RURAL TECHNOLOGY

LECTURE NOTES

VOLUME I

A Short Term Course
Sponsored under the
Quality Improvement Programme
Ministry of Education
Government of India

20th March - 3rd April 1981

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353

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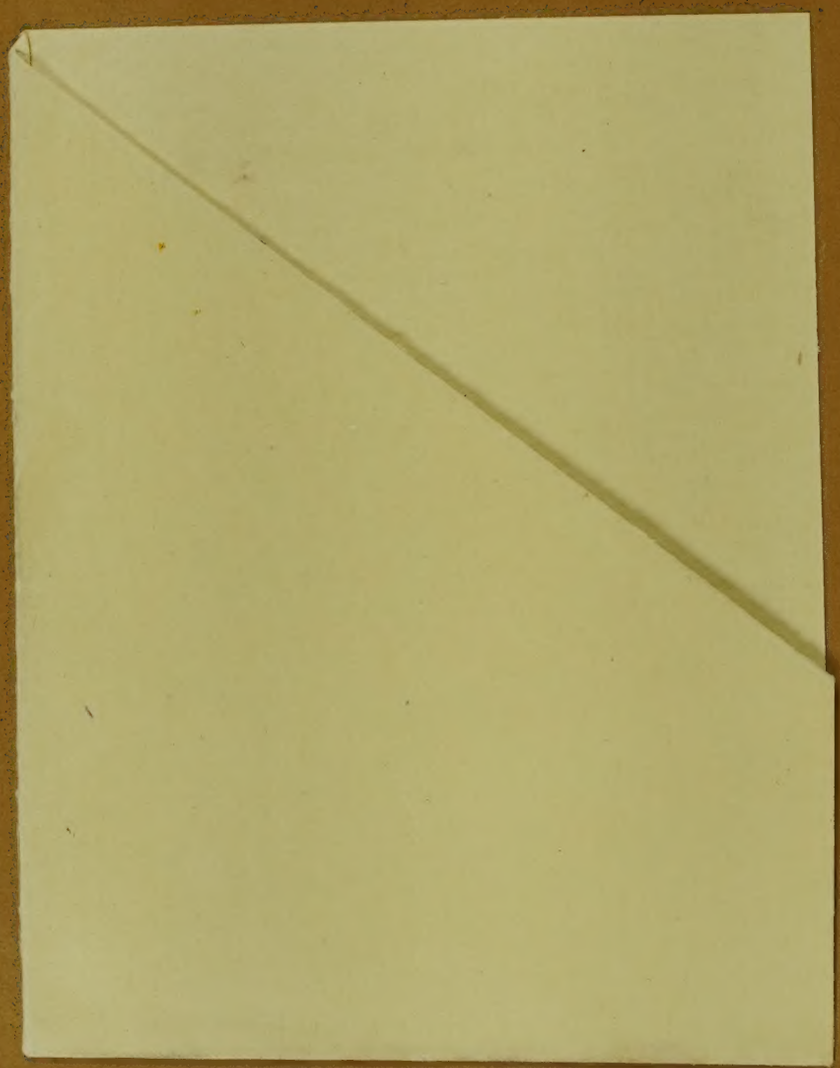

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A S T R A

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INTRODUCTION

The Indian Institute of Science is one of the oldest institutions in India. It was founded by Jamsetji Nusserwanji Tata in 1911.

Today, it has 22 departments devoted to engineering and the basic sciences, plus a few special centres for "frontier" areas such as molecular biophysics. There are 304 faculty members and 1136 students of whom 532 are in the Ph.D. Programme. The recurring expenditure of the Institute was Rs.28.2 million in 1976-77.

In its approximately 70 year old history, the Institute has made several distinguished contributions to Indian science and technology, and many great names like Raman, Bhabha and Sarabhai have held positions in the Institute. Thus, it may be considered to be one of the premier institutions in the country.

Unfortunately, most educational, scientific and technological institutions in developing countries tend to be alienated from the needs of the rural poor and their traditional technologies, and are pre-occupied with work which is largely irrelevant to rural problems.

ORIGIN OF ASTRA

A growing awareness of this phenomenon led the Indian Institute of Science to form a cell for the Application of Science and Technology to Rural Areas with the acronym ASTRA meaning "weapon" in Sanskrit.

ASTRA was formally created in August 1974 as a voluntary group to initiate, catalyse, sustain and grow in the Institute work of relevance to rural development. ASTRA, therefore, was born with a well-defined mission, viz., the generation and diffusion of technologies appropriate for rural development, and the promotion of the sciences underlying these technologies. To achieve this, ASTRA formulated an innovative approach which is based upon its view of rural development as a socio-economic process directed towards

(a) satisfaction of the basic needs of the rural population, starting with the needs of the rural poor;

(b) increasing rural participation and control in order to promote the self-reliance (as distinct from self-sufficiency) of villages;

(c) harmony with the rural environment to ensure the sustainability of development.

The crux of this approach is a formal commitment to a neighbouring rural area. An awareness of the real problems of the people cannot be acquired from the isolation of the Institute; it must be actively pursued by identifying the felt needs of rural people through direct interaction with them. The selection of technologies appropriate to rural development must be the culmination of a process of interaction with the prospective beneficiaries, consisting of the following steps:-

(a) generation of a range of technological options for the satisfaction of the identified felt needs;

(b) presentation of these options to the people;

(c) enlisting the active participation of the people in the selection of that option/those options most appropriate to their development.

The process consists of dispelling ignorance through dynamic interaction with the people, i.e., the discovery of appropriateness through flows of information, suggestions, criticisms, etc., from the people and to the people.

The generation of technologies must be distinguished from the diffusion of technologies - whereas the entire responsibility for generation can be assumed by an institution of education, science and technology, the diffusion of technology necessarily requires the collaboration of several types of institutions (people's organizations, development agencies, raw materials procurement and product marketing organizations, financial institutions, etc.). ASTRA's approach, therefore, is to concentrate on technology generation, and with regard to large-scale technology diffusion to promote it by participation in multi-institutional teams.

IMPLEMENTATION OF ASTRA APPROACH

In implementing its approach, ASTRA has focussed on two major lines of activity.

The first involves the establishment and operation of an extension centre amidst a cluster of villages near Bangalore to acquire a grass-roots understanding of the felt needs of the people through direct interaction with them, to expose the people to a wider range of technological options, and to understand technology diffusion problems by micro-diffusion in the cluster of villages. Incidentally, the Extension Centre is also intended to provide Institute faculty and students with simple basic facilities for living and working in a rural environment.

The second line of ASTRA activity involves the introduction of projects, studies and researches of rural relevance the academic programme of the Institute, i.e., into its B.E. and

M.E. projects and courses, its Ph.D. and faculty research, and its sponsored projects.

ASTRA PROJECTS AT THE INSTITUTE

Thus far, ASTRA projects are in the areas of (1) Energy, (2) Building, (3) Water, (4) Agro-processing, (5) Resources, (6) Transport. The choice of projects has been the result of a compromise between the interests of Institute faculty members and the felt needs of people in the cluster of villages around the Extension Centre.

(1) Energy: The energy projects fall into three sub-categories: (a) Rural Energy Planning, (b) Alternative Energy Sources, (c) Energy Devices and Applications. Under Rural Energy Planning come the projects on rural electrification, rural energy consumption patters, scope for wind energy utilization, biogas-based energy centres for villages, and the assessment of various energy sources. The projects on Alternative Energy Sources are on low-cost windmills, design and optimization of biogas plants, biogas-fuelled spark-ignition engines, methane enrichment of biogas by carbon dioxide separation, and energy forests. Of the various energy devices and applications being studied/developed are biogas burners, biogas melting furnaces, village "chulas" (cooking stoves), solar airconditioning and water heaters for sericulture, and wickless kerosene stoves.

(2) Building: Four sub-categories of building projects are in progress:- (a) System studies, (b) Walls, (c) Roofs and (d) Construction. The system studies consist of a survey of rural housing, the development of a systems approach to rural building technology, a study of the role of transport in building activity and determinations of the energy content of building materials. The projects on Walls involve investigations of rammed earth, soil cement blocks and compacted mud blocks. Ferrocement and bamboo-polythene-lime surki roofs are being

investigated. Under the category of construction activities come the projects on the construction of the biogas laboratory at the Institute and the dormitory and faculty houses at the Extension Centre.

(3) Water: Water Harvesting and Water Lifting are the two basic sub-categories of the projects related to water. The Water Harvesting projects involve studies on rainwater collection from roofs and farm-ponds, and the Water-lifting projects are on scooter-tyre water pumps, modification of handpumps, fluidyne pumps and a survey of water-lifting devices.

(4) Agro-processing: The agro-processing projects deal with decentralized processing of agricultural products and residues. They include the production of cellulose fibre from groundnut shells, edible cellulose from rice husk, plastics and plasticisers from castor oil, sodium silicate from rice husk, lime production on a small-scale, calcium carbonate from biogas, rice husk ash cement, rope, paper, wax and hecogenin from sisal, and small-scale jaggery production.

(5) Resources: The projects on resources involve studies of bamboo resources in Karnataka and of villages as eco-systems.

(6) Transport: The projects on rural transportation consist of studies on bullock carts and on pedal-powered vehicles.

ASTRA EXTENSION CENTRE IN UNGRA VILLAGE

An Extension Centre has been established 113 kms from Bangalore on the outskirts of Ungra village in Kunigal Taluk, Tumkur District, Karnataka State. 55 acres of government land which was once used for a seed farm and then for a horticultural training school, have been secured from the government on long lease. The three buildings, which were constructed for the seed farm, have been repaired and brought back into use as accommodation for Institute staff and students engaged in projects. The

Extension Centre has access to about 15 villages within a 3 kms radius.

The work at the Ungra Extension Centre can be classified into five categories:- (1) Natural Resource Surveys, (2) Energy Studies, (3) Agriculture, (4) Water, and (5) Building.

(1) Natural Resource Surveys: Surveys of flora and fauna in Ungra, and of the land and soils in the Extension Centre have been carried out. An aerial remote sensing survey has also been done. A meteorological station has been established and data is being collected regularly. The biomass productivity of Ungra village has been investigated in detail.

(2) Energy Studies: A detailed survey of rural energy consumption patterns has been carried out for Yedavani, Pallerayanahalli, Ungra and Kagganahalli in the first phase, and for Ungra, Pura, Suggenhalli, Kilara, Arjunahalli and Hanchipura in the second phase. A biogas-based energy centre for Pura has been designed, and is now under construction. An energy forest is being grown on part of the Extension Centre land. A study has been made of energy consumption in a brick clamp at Ungra. A survey of "chulas" at Pura has been carried out. A windmill has been installed at the Extension Centre and its performance is under study.

(3) Agriculture: Crop production on a limited scale has been taken up. In addition, experiments on programmed vegetable gardening are in progress both in the Extension Centre and in the Ungra school.

(4) Water: Studies on water harvesting have involved the construction of a minor tank (100 ft long x 6 ft high with 50,000 cft capacity) and of farm ponds. Water lifting projects include field testing and studies on modified handpumps and on scooter-tyre pumps.

(5) Building: Alternative building technologies have been tried out in the construction of a dormitory of 1540 sq.ft. plinth area and a faculty house of 484 sq.ft. plinth area.

Interaction with the people from the neighbouring villages has taken place through (1) the energy surveys, (2) the discussions on the community biogas plant under construction at Pura, (3) the enquiries regarding the ASTRA windmill, (4) the use of the ram for compacting mud-blocks, (5) the vegetable gardening experiment carried out in the Ungra school, (6) the development of "chulas", (7) the training of village youth as technicians, and (8) the visitors to the Extension Centre.

The Ungra Extension Centre has provided a grass-roots base for the understanding of technology diffusion into the cluster of neighbouring villages. This is micro-diffusion. To achieve diffusion on a larger-scale, ASTRA has envisaged other mechanisms: (1) meso-diffusion through the Karnataka State Council for Science and Technology whereby proven technologies, e.g., modifications to handpumps, are disseminated by government development agencies to all parts of Karnataka, (2) macro-diffusion through national organizations, e.g., All-India Handicrafts Board, (3) bilateral diffusion by linkages with voluntary group and with like-minded institutions in other parts of India, and (4) educational programmes to be organized by ASTRA, e.g., the two one-day seminars on Handpumps for about 300 government engineers from the Department of Public Health Engineering of Karnataka.

LESSONS FROM ASTRA'S EXPERIENCE

The lessons drawn from ASTRA during its first 4 years have amply validated its creation:

(1) The model for the institutional generation of technologies appropriate for rural development, consisting of (a) the establishment of extension centres in rural areas, and (b) the

incorporation of a commitment to those rural areas into the work programme of the institution, is rapidly spreading.

(2) The interaction with the rural population through the Extension Centre has lent considerable support to ASTRA's methodology for selecting appropriate rural technologies.

(3) ASTRA's methodology has clarified what role scientists/engineers should play as scientists/engineers. They should translate the felt needs of people into technical problems, and then carry out the research and development work to widen the range of technical options which can satisfy the felt need.

(4) Traditional technologies (which may have become sub-optimal because of changed conditions, constraints and possibilities) can become a rich source of appropriate technologies if their rational scientific basis is understood and they are qualitatively improved with marginally costlier inputs of modern science and engineering.

(5) ASTRA's concept of widening the range of technical options available to the people has led to a powerful methodology for discovering R & D perspectives. If, for instance, a rural house is viewed as a system with the foundation, walls, roof and services as system components, then, for each component, there are a number of options. Further, various integrations of component options result in various system options with increasing performance efficiencies at incremental cost increases. It is from such a range of system options that the people can meaningfully select appropriate options. Accepting such an approach, the generation of an R & D perspective (and therefore programme) simply involves (a) R & D on all available and new component options, and (b) R & D on all system options.

(6) ASTRA's experience demonstrates that simple products/processes invariably require sophisticated thinking/research/development and that, therefore, appropriate rural technology

is advanced high technology (and not primitive low technology) if the advanced/"high" character of a technology is to be judged by the extent of modern scientific and engineering thinking and not by the trivial criterion of scale of production or origin in the industrialized countries.

(7) Since there is no established approach for appropriate technologies, there is no alternative to starting from fundamentals. This experience of ASTRA implies that the base of fundamentals must be stronger to generate rural/small-scale/decentralized technologies than to imitate/adapt urban/large-scale/centralized technologies. Of even greater importance is the lesson that efforts to generate appropriate rural technologies necessarily require more, not less, simultaneous emphasis on basic research and fundamental science.

(8) ASTRA's strategy of commitment to the problems of people in a specific rural area has led to an intense learning process through which technical capability is acquired rapidly, effectively and cheaply with the existing infrastructure. The environment is the best teacher provided that there is commitment to that environment.

(9) ASTRA's projects have turned out to be as scientifically sophisticated and technically challenging as any other work in the Institute. Also, the strong interaction with the people in the selection and generation of appropriate rural technologies has led to a widening participation in innovation. It is this democratization of innovation which seems a far more promising method of promoting a scientific temper amongst the people than the usual approach of science popularization through lectures and exhibitions. In addition, ASTRA's experience has shown that the process of identifying the felt needs of people and the presentation to them of a range of technical options is a powerful method of conscientizing

scientists and engineers into an understanding of the facts and origins of rural poverty.

(10) ASTRA has become a genuine inter-disciplinary programme involving about 35 faculty members from 6 departments. This is mainly due to its mission, which is well-defined and significant. It is this mission which has attracted scientists and engineers, drawn them together, influenced them, and made their capabilities reinforce each other. It is also the mission which has made the whole become more than the sum of the parts.

THE FUTURE

It is envisaged that the future R & D work of ASTRA will involve (a) intensification of efforts in the current areas of interest, as well as (b) expansion into new areas. The main emphasis in the current areas of interest will be the development of an R & D perspective within each area, so that work can be initiated on the gaps in the perspective, and also the separate projects can be coordinated into a coherent programme. Since the present thrust of ASTRA reveals several areas crucial to rural development in which no work at all is being carried out, it is envisaged that efforts will be mounted in these areas viz., water management in agriculture, agricultural implements and machinery, health, education, etc. A Health Centre and a school at the Extension Centre are being planned.

The elaboration of these R & D programmes will be carried out in the context of attempts to elaborate a block-level plan in which resource inputs are matched to development needs in the Extension Centre region. An integral part of this effort will be an attempt to understand the basis for the self-reliance of villages, clusters of villages and blocks as eco-systems.

The mounting volume of literature on appropriate rural technologies which is constantly accumulating with ASTRA will be organized into an information system. It is intended that this information system will become a service to the large

number of institutions and groups which are engaged in generating and diffusing rural technologies. At the same time, efforts will be made to disseminate information on appropriate rural technologies developed by ASTRA and other institutions/groups. Links will also be forged with appropriate technology information systems abroad.

With the growth of understanding and expertise in various scientific and technological aspects of rural development, efforts will be made to contribute to and develop teaching programmes in the Institute.

EXPANSION OF ASTRA

Thus far ASTRA has developed only by attracting the interests and commitment of the existing faculty of the Institute. It has not acquired any faculty specifically appointed for the ASTRA programme. This process of transforming the interests of existing faculty is approaching saturation. Hence, the implementation of future programmes requires the recruitment of faculty specifically dedicated to the ASTRA programme, along with support staff and more intense student involvement. In short, now that ASTRA has demonstrated its viability and significance, a major expansion of ASTRA both at the Institute and at the Extension Centre is under consideration.

7-3-'81.

RURAL DEVELOPMENT

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Lecture 1.1
Rural Technology Course

RURAL DEVELOPMENT

Amulya Kumar N. Reddy

Introduction

Over the past 25-30 years, a large number of countries, particularly in Asia and Africa, achieved political independence, and set out on the path of economic transformation. A large number of industries were established; a great deal of modernization occurred with the introduction of western food, clothing and houses, hospitals, universities, cars, airlines, telephones, radio, television, etc. At the same time, many of these countries sought to modernize their agriculture, particularly through the so-called green revolution based on high-yielding varieties and inputs of fertilizer, pesticides, water, etc. The Gross National Product (a measure of the amount of goods and services produced by the country) has shown impressive increases in most of these countries.

The Growth-and-Trickle-Down Hypothesis

This whole pattern of change was inspired by a simple belief, viz., all that a backward country needs to do to develop is to retrace the path followed by the industrialized countries and to adopt the goals which they pursued. In particular, the aim should be to equate development with growth and to maximize growth in the volume of goods and services, i.e., to maximize the GNP. By implementing such a strategy, it was assumed that the abject poverty of the masses in developing countries would be eliminated by the benefits of growth trickling down to the poorest sections of society - this is the growth-and-trickle-down hypothesis.

Experience of the Developing Countries

By now, sufficient time has elapsed to see the results of such a growth-and-trickle-down strategy. The main result has been the perpetuation, consolidation and aggravation of what has been termed a "dual society" — a small, politically powerful elite (constituting a mere 10% of the population and consisting of industrialists, landlords, bureaucrats, professionals, and white-collar labour) living in conspicuous affluence amidst the abject poverty of the politically weak masses, and islands of urban splendour amidst vast oceans of rural poverty. Recent history also shows that, in most of these backward countries, the greater the industrialization on the pattern of the advanced countries, the greater the polarization into a dual society, the wider the gap between the elite and the masses, and the larger the percentage of people pushed below the poverty line.

The New Approach to Development

The experience of the past 30 years shows that development must not be equated with growth. For more important than the sheer magnitude of growth is the structure and content of growth, and the distribution of its benefits. Once a particular pattern of growth takes place, neither its structure and content, nor its benefits, can be easily altered. Growth for the benefit of the elite, e.g., processed and packaged foods, expensive cloth, luxury houses, capital-intensive private hospitals, richly-endowed universities, and private cars, can never be transformed into growth for the masses, i.e., cheap food and cloth, low-cost housing, mass health care, education and transportation. The GNP by itself does not reveal what constitutes it, e.g., cars or buses, or who benefits by it, i.e., the elite or the masses.

For over a decade, therefore, the concept of development has been re-formulated from a totally different standpoint.

The starting point has been the pervasive and abysmal character of poverty and the existence of glaring inequalities. The crux of poverty is the fact that the basic needs of the bulk of the population have not been satisfied. Even elementary minimum standards of food, clothing, shelter, health and education have not been achieved. The distribution of the goods and services necessary for the satisfaction of these needs cannot be a matter of charity, for that would be incompatible with the dignity of the recipients. And, therefore, human beings need to earn, in the noblest sense of the term, their food, clothing, shelter, health and education. Thus, employment also must be considered a basic human need.

Poverty and the lack of basic needs is only one side of the coin; the other side is the existence of inequalities in assets and purchasing power. For, an inequality in the distribution of purchasing power leads to a skewed demand structure, which in turn makes industry, agriculture and the services produce a pattern of goods and services - the so-called product-mix — catering more to the demands of the rich than the needs of the poor. Thus, the rich get richer and the poor poorer, i.e., comparatively speaking, relative poverty increases. Inequality, therefore, is recursive and increases with time.

If this process is to be reversed, industry, agriculture and the services must assign priority to satisfying the basic needs of the poorest, so that inequalities are diminished and poverty reduced.

There is another, and equally important, aspect of basic needs. This concerns the question, not of the extent to which they are satisfied, but how they are satisfied. Even a highly repressive dictatorship can successfully tackle the task of producing the necessary goods and services and distributing them

to an oppressed populace so that its basic needs are satisfied. In this process, workers may be mere cogs in the production process, and the purpose of work at the individual level, and of production at the societal level, is neither comprehended nor voluntarily accepted. Further, social participation in the definition of social goals and social control over the directions of social change can be completely prohibited. A relationship of abject dependency of the ruled on the rulers can grow, i.e., the spirit of self-reliance in the people can be destroyed. Thus, even though basic needs are satisfied, the quality of life, which also depends upon meaningful work and a people's participation and control over its destiny, can be miserable. The concept of development must include the manner in which basic needs are satisfied and emphasise social participation and control, so that self-reliance is strengthened.

The environmental implications of satisfying basic needs are also of crucial importance. The point is that the satisfaction of basic needs requires the production of goods and services, and production through industry, agriculture and the services involves impacts on the biogeophysical environment - resources (inputs) are transformed, and discharges, emissions and by-products, apart from the intended products (outputs), are invariably released. The land that man uses, the air he breathes, the water he drinks, the food he eats, the peace he requires, the beauty of nature he enjoys, etc., are all inevitably changed. Development, therefore, cannot take place without a perturbation and alteration of the environment, but are these environmental changes such that they will make further development extremely difficult or even impossible. So, development must be sustainable over the long run, and for this to be possible, the process of satisfying basic needs must not result in a society destroying its resource base and its environment. If development is to be sustainable, it must be in harmony with the environment.

Development, therefore, must be defined as a process of socio-economic change directed towards

(1) satisfaction of basic human needs (food, clothing, shelter, health, education, transport/communication, etc., and employment which makes all this possible), starting from the needs of the neediest, in order to reduce inequalities between and within countries;

(2) social participation and control in order to strengthen a self-reliance that grows from within and to prevent concentration of economic and political power; and

(3) ecological soundness in order to achieve harmony with the environment and make development sustainable over the long run.

What is Rural Development?

A particular aspect of development is rural development which, as a corollary, should be defined as a socio-economic process directed towards

(a) satisfaction of the basic needs of the rural population, starting with the needs of the rural poor, in order to reduce inequalities between different sections of rural society and between rural and urban areas;

(b) increasing rural participation and control in order to promote the self-reliance (as distinct from self-sufficiency) of villages;

(c) harmony with the rural environment to ensure the sustainability of development.

This definition of rural development clarifies several points. It specifies what goods and services must be emphasised - those that satisfy the needs of rural society,

in particular, the needs of the rural poor. It stipulates which sections of rural society must be the primary targets and beneficiaries of rural development - the neediest. It indicates whether rural society is moving towards the objective of rural development - are inequalities in rural society and between the rural and urban sectors decreasing? is the participation of rural society, and particularly the rural poor, in the development process increasing? is the ecological soundness of this process increasing?

The definition suggested here also helps in the clarification of a major issue - can rural development be considered as a process that can be separate from urban development? In actual fact, urban growth in most developing countries has been at the expense of rural development. The towns and cities have a parasitic impact on villages with what has been described sometimes as a centre-periphery relationship in which the centre (city/town) exploits the periphery (rural areas). Unless the underlying mechanisms for this parasitism are dismantled, rural development cannot take place in symbiotic relationship with urban development; there will only be a more efficient and effective exploitation of the rural areas. Thus, rural development must be seen as a part of total development of which urban development is the other integral part.

TECHNOLOGY AND SOCIETY

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Lecture 1.2.1(a)
Rural Technology Course

TECHNOLOGY AND SOCIETY

Amulya Kumar N. Reddy

Introduction

It is well known that the pattern of technology is shaped by, and in turn, shapes, the society in which this pattern is generated and sustained. That is, society influences technological developments, and these developments change society. More specifically, technology responds to social wants, which are in turn modified and transformed by technology through a causal chain, or rather causal spiral.

A Simple Model of Technology-Society Interactions

A deeper understanding of technology-society interactions is facilitated by the simple model shown in Figure 1.

Every society generates wants, but all social wants are not necessarily responded to by the institutions responsible for the generation of technology, viz., the educational, scientific and technological institutions. There is a process of filtering these wants, so that only some of them are transmitted as demands upon technological capability, and the rest are bypassed by these institutions. In other words, there are ignored wants which institutions avoid in their research and development programmes.

This filtering process is usually operated by decision-makers, firstly, in the bodies which control the research and development institutions (i.e., by decision-makers in government and corporations), and secondly, in the institutions

themselves. These decision-makers are either conscious agents of political, social and economic forces, or unconsciously influenced by these very forces.

In untempered market economies, only wants which can be backed up by purchasing power become articulated as demands upon the research and development institutions, and the remaining wants are bypassed, however much they may correspond to the basic minimum needs of underprivileged people. Thus, like all commodities in these economies, technology too is a commodity, catering to the demands of those who can purchase it, and ignoring those who cannot afford it.

The generation of technology involves the so-called "innovation chain" which is the sequence of steps by which an idea or concept is converted into a product or process. This sequence of steps varies with the circumstances, but can often be schematically represented thus:

Formulation of research and development objective ⟶ idea ⟶ Research and development ⟶ Pilot-plant trial ⟶ Market Survey ⟶ Scale-up ⟶ Production/product engineering ⟶ Plant fabrication⟶ Product or process.

It is essential to note that socio-economic constraints and environmental considerations enter the process in an incipient form even at the stage of formulation of the research objective, and then loom over the chain at several stages. These constraints are in the form of preferences or guidelines - or paradigms, to use the currently fashionable word - for example, "Seek economies of scale!"; "Facilitate centralized, mass production!"; "Save labour!"; "Automate as much as possible!"; "Don't worry as much about capital and energy (in the days before the energy crisis) as about productivity and growth!"; "Treat polluting effluents or emissions as externalities!"; "Only worry about the unit cost of the product

from the point of view of the entreprise, don't worry about social costs, e.g., damage to community health or increased load on the transport system or exhaustion of non-renewable natural resources!"; etc.

Thus, every technology that emerges from the innovation chain already has congealed into it the socio-economic objectives and environmental considerations which decision-makers and actors in the innovation chain introduced into the process of generating that technology. Further, at a previous stage in the spiral the very decision to respond to a particular social want by generating the necessary technology is the result of a deliberate filtering process wielded by decision-makers.

The technology that emerges from the innovation chain will become an input, along with land, labour and capital, to establish an industry or agriculture or a service if and only if the aforesaid socio-economic and environmental constraints are satisfied. Thus, it is not only the technical efficiency of the technology, but also its consistency with the socio-economic values of the society, which determine whether a technology will be deployed and utilized.

Social wants are not static. The products and services that are produced create new social wants, and in this process the manipulation of wants through advertising, for example, plays a major role, and thus the spiral:

Social wants ——→ Products/Services ——→ New Social wants ——·····→

Technological Shaping of Society

Since social wants, which are the driving force of technological development, are themselves transformed by technology (and its embodiment in industry, agriculture and the services), it is clear that technology shapes society.

Social Conditioning of Technology

The model also reveals that every pattern of technology is socially conditioned. Technology is a product of its times and context, and bears the stamp of its origins and nurture. It is in this sense that technology can be considered to resemble genetic material that carries the code of the society which conceived and nurtured it and, given a favourable milieu, tries to replicate that society. The replication is neither automatic nor inevitable, it is successful only when a host of environmental factors are favourable - hence, the argument is not tantamount to technological determinism. Further, it has been emphasized that technology itself is socially conditioned - hence technology is not viewed as an autonomous factor and a motive force outside society. Of course, all this is obvious to archeologists who must proceed from the material products of technology, i.e., tools, artifacts, etc., to reconstruct the vanished society and its culture, and to social anthropologists who cannot but consider technology-industry/agriculture-society interactions.

The Technology-Society Model for Stratified Societies in Strong Interaction with the Industrialized Countries

The model of technology-society interactions presented above is valid for isolated and homogeneous societies. But, it is too simplistic for a country like India. Firstly, like most developing countries, India is a statified society. In the first approximation, this stratification can be represented as a dual society - a society of the elite, and a society of the masses, which may not be isolated from the former, but is separated from it by a wide chasm of incomes, consumption patterns, attitudes and life-styles. Secondly, the elites of these developing countries practice a philosophy best described thus: "all that is rural is bad, all that is urban is better, and all that is foreign is best". This means that there is a strong influence of the life-styles of the developed countries

upon the elites in developing countries. Hence, countries like India neither have isolated nor homogeneous societies, and the model of technology-society interactions must be elaborated to deal with stratified societies in strong interaction with the industrialized countries.

One possible elaboration (which is closely related to that proposed by Herrera*) is shown in Figure 2.

Little significance must be attached to the sizes of the circles, though

(a) in the case of the row: Society, the circles 1-1, 1-2, 1-3 have been drawn very approximately according to the relative sizes of the populations; and

(b) in the case of the rows: Educational, Scientific and Technological Institutions, and Technology, the circles 3-1, 3-2, 4-1 and 4-2 have been drawn very approximately according to the relative magnitudes of the R and D expenditures.

The problem of the urban poor in developing countries is indeed a serious, and more visible, problem. Nevertheless, the urban poor have not been included in the present scheme because

(a) their numbers are much smaller than those of the rural poor;

(b) being subject so much to the powerful demonstration effect of the life-styles of the urban elites, they share to a considerable extent similar aspirations; and

(c) their survival in urban metropolises generates infrastructural requirements similar to those of the elites.

Whereas there is a tremendous overlap between the wants in developed countries and those of the elites in developing

*Dr.Amilcar O.Herrera, "Scientific and Traditional Technologies in developing countries", Chapter 13 of "The Art of Anticipation", Martin Robertson (1975), London.

countries (cf. circles 2-1 and 2-2), it is a characteristic of a dual society that there is virtually no overlap between the wants of the elite and the rural poor in developing countries (cf. circles 2-2 and 2-3). The elite wants tend to be modelled on the pattern of the developed countries, in contrast to the rural poor whose wants correspond to the very basic minimum needs of food, shelter, clothing, health, employment, etc.

In dual societies, the bulk of the decision-making is in the hands of the elites who are, therefore, responsible for the filtering process which selects out some wants for onward transmission as demands upon the educational, scientific and technological institutions and shelves other wants by giving them relatively little attention. In most cases, this elitist filtering process functions in such a way that:

(a) the wants of the elites are almost wholly transmitted as demands requiring technological answers, and

(b) the wants of the rural poor are largely ignored even though they are an expression of urgent minimum needs.

Since it is the satisfaction of these basic needs which constitutes the essence of development, it follows that an elitist filtering process is incompatible with development.

The demands of the elite are picked up by educational, scientific and technological institutions through the agency of industry in the developing and developed countries, both of which sense in these demands a major market. It is important, however, to note that industry in developing countries is of two categories:-

(a) indigenous industry which derives its technology from the national educational, scientific and technological institutions; and

(b) industry which may be owned by government, native entrepreneurs or by multinational corporations (or by two or three of these in different ratios), but which is based on imported technology generated in the institutions of developed countries.

Between these two categories, the linkage of the demands of the elite is very much stronger with the second category of local industry, viz., that based on imported western technology developed by the educational, scientific and technological institutions of the developed countries. This is why the strong linkage 2-2 ⟶ 3-1 is shown with a continuous line and the weak linkage 2-2 - - - -→ 3-2 with a dashed line.

The operation of the filtering process to block the transmission of most of the wants of the rural poor, i.e., the basic minimum needs of the majority of the poverty-stricken population, from the educational, scientific and educational institutions is emphasised by the absence of a linkage between the circle 2-3 and either circle 3-1 or circle 3-2. Of course, the linkage is not zero - for instance, when the rural poor suffers from communicable epidemic diseases, the elites are also vulnerable, and such needs of the rural poor are obviously responded to effectively. Thus, the filtering process is not conducive to rural development which in developing countries must constitute a major aspect of the development process.

In the absence of institutions to develop technologies to meet the needs of the rural poor, the latter have no choice except to fall back on traditional technologies based on the reservoir of empirical knowledge accumulated through the centuries. (cf. the linkages 2-3 ⟶ 4-3 and 4-3 ⟶ 2-3).

There is very strong linkage 3-1 ⟶ 3-2 between the educational, scientific and technological institutions of developed countries and those in developing countries, the

latter being modelled very closely on those of the former. In fact, these institutions in developing countries derive their emerging ideas for research and development, its trends and fashions, its stream of inspiration, its experimental techniques and instruments, its criteria of excellence and its source of recognition from the counterpart institutions in the developed countries. Superimposed on this process is the fact that developing countries receive education and training for a large proportion of their personnel, and in many countries a large influx of expatriates and "experts", from developed countries.

In the generation of technology, the educational, scientific and technological institutions of developing countries invariably start with imported western technology as a starting-point and as a model, hence the linkage 4-1 ⟶ 3-2. Thus, they emerge (linkage 3-2 ⟶ 4-2) after a process of imitation, adaptation and innovation (the innovation, rarely!) with a technology which has been described as naturalized, i.e., adapted western technology.

The satisfaction of the demands of the elite is much more through western technology (this strong linkage is shown by a continuous arrow 4-1 ⟶ 2-2) than through naturalized technology (this weak link is shown by the dashed arrow 4-2 - - - - → 2-2).

It is necessary to emphasize some important conclusions from this elaborated model of technology-society interactions in stratified developing societies in strong interaction with industrialized countries.

Firstly, the characteristics of these dual societies are such that the filters do not emphasise the transmission of basic human needs of the rural poor as demands upon the technology-generating institutions - cf. the absence of linkages between

the social wants of the rural poor (circle 2-3), and the national and developed country educational, scientific and technological institutions (circles 3-2 and 3-1). The magnitude of the R and D funding for problems related to these basic needs is usually a clear indicator of this bias, for it is very often significantly less than that for problems related to defence (of underdevelopment?) and to those aspects of the industrial, agricultural and services sectors devoted to the demands of affluent elites.

Secondly, the intellectual domination of the developed countries over the educational, scientific and technological institutions in the developing countries leads, in the latter, to a virtually unexamined and unquestioned introduction of alien and inappropriate preferences, guidelines and paradigms into the innovation chain, for example, the implicit faith in "economies of scale".

Thirdly, there is the problem of the thrust of technological capability. The conscious attempt to emulate the institutions of the developed countries results in the educational, scientific and technological institutions of the developing countries acquiring patterns of technological capability distorted towards the problems preoccupying the developed countries, i.e., towards problems largely unrelated to the development needs of developing countries. This distortion is only accentuated by the large-scale attempt of developing countries to get their manpower trained in the developed countries, for the most significant result of such training is an increased alienation from domestic developmental tasks. No wonder that most foreign-returned (if they do return!) scientists and engineers spend the bulk of their remaining professional lives continuing the themes of their foreign researches, even though the stark reality outside their laboratories and workshops is clamouring for a local commitment and a native orientation. 1.2.1(a)

Technology is not Neutral in Stratified Societies:

The final and most important conclusion is that decision-making elites in stratified societies always seek to choose and spread those technologies which consolidate, perpetuate and promote their vested interests. They use technology as an instrument for the achievment of their ends. Thus, in the conflict of interests between the elites and the masses of a dual society, technology must not be considered a neutral force untainted and above the conflict. The implication is that in considering any technology one must always examine which sections of society benefit from the technology and what role it plays in the conflict of social forces.

Figure 1. Simple Model for Technology-Society Interactions

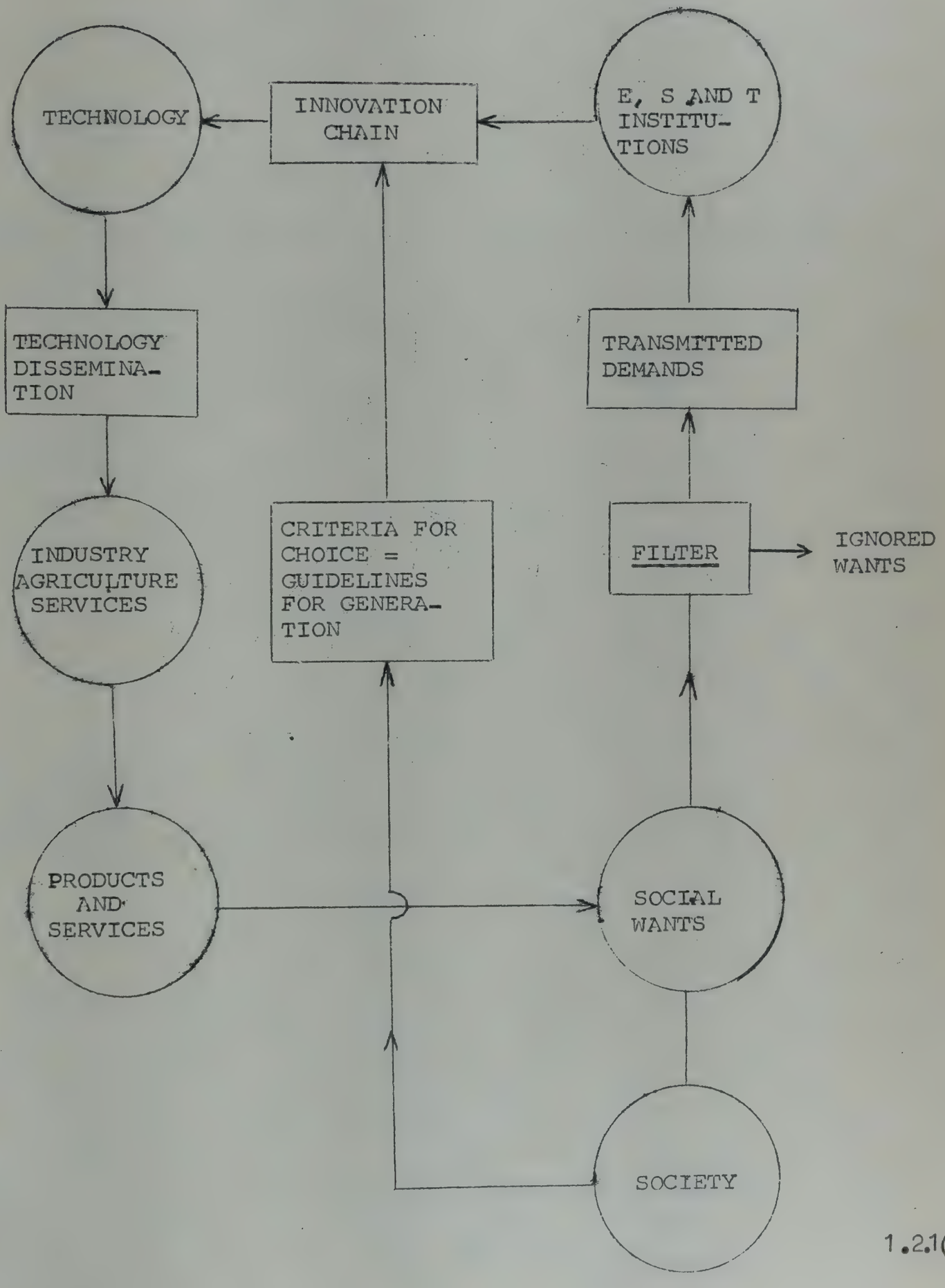
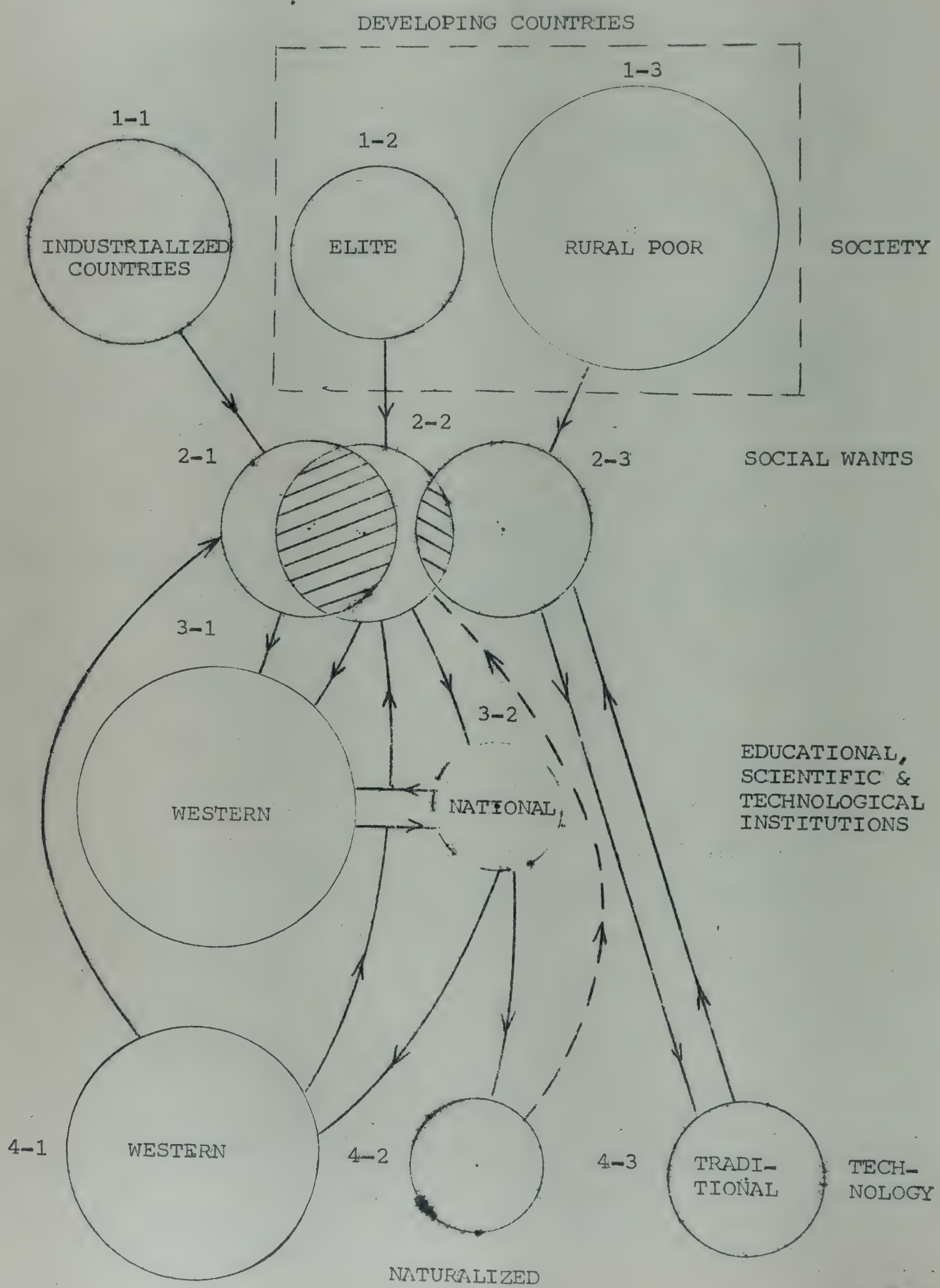


Figure 2. Technology-Society Model for stratified developing Societies in Strong Interaction with Industrialized Countries.



APPROPRIATE RURAL TECHNOLOGY

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Lecture 1.2.1(b)
Rural Technology Course

APPROPRIATE RURAL TECHNOLOGY

Amulya Kumar N. Reddy

Introduction

The cultural and intellectual dominance of the developed countries over the developing countries has been so overwhelming that any thought of development automatically conjures up a picture of the pattern of technology (which for convenience shall be referred to as Western technology) that obtains in Western Europe and North America. This picture is only reinforced by the fact that the centrally planned economies of Eastern Europe and Soviet Union, and the industrialized country of the East, Japan, have also adopted virtually identical patterns. A fundamental question, therefore, arises: is the Western pattern of technology a unique, inevitable and unavoidable pattern which developing countries must necessarily follow?

The Western Pattern of Technology

In exploring this question, it must first be realized, following from the model of technology-society interactions presented in the previous lecture, that, like all patterns of technology, the current western pattern of technology is also a product of specific historical conditions, viz., the epoch of history corresponding to the past 30-80 years. In this epoch, a set of industrialized countries were first able to control the politics of a number of colonies, and then after these countries became politically independent, to dominate the economics of these ex-colonies. These relationships of dominance enabled the developed countries to commander, and/or

enjoy from the developing countries, natural resources, including non-renewable minerals and fossil-fuel energy, at much lower prices than would have been the case if relationships of equality had prevailed. For instance, the prices of raw materials from the Third World have not risen as sharply as the prices of manufactured goods from the industrialized countries. (The 1973 oil price hike and the conflicts at UNCTAD IV and the Paris North-South Conferences are all part of the drive to redress these historically-enforced inequalities.) This situation has also resulted in the accumulation of capital taking place at a rate and in volume which would not have otherwise been possible. At the same time, the industrialization of the developed countries has invariably taken place amidst shortages of labour.

All these factors, i.e., the easy availability and low prices of raw materials, energy and capital, and the scarcity of labour, have had an overwhelming influence on the pattern of Western technology. This is because every technology is only viable within certain limits (upper or lower) of the prices of raw materials, energy, capital and labour, and if the prices of one or more of these inputs changes drastically, the validity of the technology may be undermined. The point has been dramatically demonstrated with the vast number of energy-intensive western technologies based on the cheap Middle East oil of the pre-1973 days, all of which are now undergoing exhaustive reassessment. Thus, the old (and still prevailing international economic order) has resulted in the capital intensiveness, energy-profligacy, recklessness with regard to non-renewable natural resources and labour-saving character of the western pattern of technology.

The second crucial feature of the period of history which spawned the western pattern of technology is that the vast majority of the technological innovations underlying this pattern have emanated from the basic driving force of capitalism,

viz., the maximization of profit and accumulation. This intrinsic compulsion to minimize internal costs of enterprises and to disregard as externalities all effects on the social and natural environment of the enterprises has led to the three intrinsic tendencies of Western technology:

(1) amplification of inequalities between and within countries;

(2) increase of alienation of men from each other and from their work, and diminution of social participation and control; and

(3) degradation of the environment.

The Intrinsic Tendencies of Western Technology

The intrinsic tendency of amplifying inequalities between and within countries results from the following features:

(1) Western production technology has become increasingly capital-intensive, and therefore gravitates to areas and locations where that capital can be mustered and exploited, i.e. usually towards rich nations and away from poor nations, and towards the urban areas of developing countries at the expense of their villages;

(2) The associated increase in energy intensiveness leads to increasing automation and decreasing dependence on labour, i.e. in the absence of careful central planning, to greater unemployment. This produces, in developed countries, relative poverty for the minority and, in developing countries, a potentially catastrophic accentuation of the gap between affluent elites and the poverty-stricken masses.

(3) Having largely solved the minimum needs of the populations in developed countries, Western product technology is increasingly oriented towards luxury goods for private consumption, and towards military applications. For, when

there is inequality in the distribution of purchasing power, the resulting skewed demand structure drives such technology to respond more avidly to the luxury demands of the rich and other non-essentials, and assign lower priority to the basic needs of the underprivileged.

The inherent tendency of increasing alienation and diminishing social participation and control is an inevitable result of the following features:

(1) Western production technology has relentlessly pursued so-called economies of scale, mass production and automation. In doing so, it has generated a highly skewed pattern of demand for skills. Only the few are required to possess a high degree of intellectual training or manual skills, while the barest minimum of intelligence and dexterity is expected from the vast majority of the working force, which naturally becomes alienated. This trend is only aggravated by the deliberate organization of the labour process to increase profits, rather than to enrich the lives of workers.

(2) But, training and skills lead to control over technology, and thereby to power — hence, Western technology tends to concentrate power in the hands of the few and deprive the majority of control over their destinies. Pushbutton warfare is the ultimate example of the technology-power equation.

(3) The virtually complete exclusion of craftsmanship and creativity from work in modern factories which are, in addition, dominated by machines, results in the alienation of men from their work.

(4) Western product technology is specifically designed to respond to and evoke demands from, those privileged with

purchasing power, and therefore results in the proliferation of luxury goods for individual consumption and the generation of overly consumption-oriented lifestyles — thus increasing alienation of men from other men.

The third intrinsic tendency of the western pattern of technology, viz., its disastrous impact on the environment, is a consequence of the following features:

(1) Western industry's obsession with an ever-increasing scale of production results in an increasing magnitude of perturbation of eco-systems (e.g., the sources of pollution become more and more concentrated and intense) till there is a real possibility of pushing them beyond the limits of stability.

(2) Western industry has generated risks to the biosphere of increasing gravity ranging from trivial and acceptable to remediable, avoidable and catastrophic, and has increased the probability of occurrence of any given category of risk. Thus, human civilization and life itself have become threatened by technological "progress", particularly in weapons.

(3) At the same time, the constant drive to manufacture products, which are ever changing in appearance and form, but similar in function and content, is the cause of the rape and exhaustion of natural resources, the alarming degree of product obsolescence and the "throwaway" philosophy.

(4) Finally, the tendency of Western technology to magnify inequality results in the very rich countries (and groups within countries) damaging the environment through over-consumption and the very poor being able to ensure their survival only at the expenses of their environment.

The Need for an Alternative Pattern of Technology

In considering the industrialization of developing countries like India, two fundamental issues must be raised:

(1) is it feasible for these countries to emulate the Western pattern?

(2) is it just and moral to do so?

The feasibility aspect is easily considered by noting that developing countries like India just cannot replicate the favourable environment which the developed countries enjoyed, particularly during the early stages of their industrialization. Very, very few of the developing countries have within their frontiers the entire range and quantity of raw materials necessary for the Western pattern of technology. Barring the OPEC countries, most of them are critically short of energy. Most of their agricultural systems have been distorted into production of commercial crops for the industrialized world resulting in frequent food deficits. They do not have captive external markets for manufactured goods, and in attempting the export drives being recommended to them, they find that their industrial technologies are not competitive with those from the developed countries. Further, it is too costly to generate competitive technology. Hence, they are forced to import Western technology. In fact, technology exports from developed countries have been considered to be the new way of reinforcing the dependence of developing countries. The current predicament of a developing country can be simply described: a country cannot arrive on the stage of history fifty years late and expect to play the same role as the countries which participated in the first acts.

It is also clear that a desperate hunger for raw materials would develop if all the developing countries attain the per capita consumption levels of the developed countries. For

instance, the USA alone is consuming about 25% of today's world oil production with a consumption of 3 tonnes per year per capita. If every Indian enjoyed the same per capita consumption level, India alone would require 63% of today's world production of a depletable natural resource. The conclusion is clear: the developed countries can enjoy their current consumption levels precisely because the developing countries are subject to deprivation, and it is extremely doubtful from a resource point of view, whether the poor nations can ever achieve similar standards as the rich.

Even if it were feasible for developing countries to emulate the Western pattern of technology, the justice and morality of such an attempt should be considered.

The whole pattern of inequality, injustice and exploitation characterizing the current international economic order is repeated within developing countries, for almost all of them are polarized into dual societies with a society of the richest 10% of the population separated by a vast chasm of lifestyles, incomes and aspirations from a society of the poorest 90% consisting mainly of the rural poor. The market economy encompasses almost exclusively the richest 10 per cent which has emerged as a politically powerful, conspicuously consuming, Western-oriented elite. At the same time, the poorest 90 per cent, and in particular the poorest 40-50 per cent, exist in poverty outside the market economy. The polarization is also associated with rural stagnation and impoverishment, with massive rural employment and underemployment, and with mass migration to metropolitan slums. Hopes that the benefits of industrial growth will percolate to the countryside and reduce income disparities have not been borne out by experience.

In fact, it appears that the Western pattern of technology upon which Indian industrialization has been based has only accentuated the evils of the dual society.

The elite, however, is the principal beneficiary -- through the luxury goods, jobs and profits - of the introduction of the Western pattern of technology. When this capital-intensive, labour-saving pattern is introduced into the capital-starved, man-power rich developing countries, the scarce capital concentrates in large urban plants and shies away from the rural economy. One result of this concentration of capital is a sharpening of the contrast in living standards and opportunities between the urban elite and the rural masses.

Another result which has to be singled out from all the others as particularly alarming is the impact on employment. Because of the capital-intensive nature of Western technology, the investment required to create jobs is extremely high, about Rs.20,000 - 2,00,000 per job (see Table 1). At this rate, industrialization on the basis of Western technology can provide employment only to restricted numbers. The backlog of unemployed (about 20 million), and the new entrants to the work-force every year (about 5 million), cannot find employment through labour-saving Western technology unless astronomically large investments are made. But, these are impossible in capital-starved developing countries. Hence, unemployment grows to serious proportions.

It is clear that the Western pattern of technology and industry sustains and consolidates the elite. In turn, the elite has consistently supported the adoption and promotion of this pattern, for example, through the policy of foreign collaboration arrangements.

Thus, the Western pattern of technology has buttressed the polarization into dual societies with small city-oriented Western elites, and large masses of poor people left out of the circle of production and consumption by the lack of employment and purchasing power. In short, the pursuit of the Western pattern has created and bolstered metropolitan islands

of Western-oriented affluence among wast oceans of rural poverty, but the islands can survive only if they do not expand significantly.

It appears that, just as the old (and prevailing) exploitative international economic order between developed and developing countries produced, and is sustained by the Western pattern of technology, the polarization of developing countries into dual societies is accentuated by the adoption of this pattern.

Further, as is the situation between developed and developing countries, the haves can have only if the have-nots do not have, in the sense that the affluence of the elites can be preserved at the expense of the misery of the masses. Such disparity cannot be associated with stability; it can be maintained only by force. Thus the exploitation, injustice and misery inherent in dual societies implies the immorality of the Western pattern of technology.

Hence, not only is the Western pattern not feasible; it is also immoral. But interestingly, what is immoral cannot be sustained, and what is not feasible over the long run is also immoral. Historical feasibility and morality seem to converge. An alternative pattern of technology must be implemented.

Technologies appropriate to Rural Development and Appropriate Rural Technologies

The alternative pattern of technology must have development as its goal, and not mere growth as has been the case in the past. This viewpoint provides a definition of appropriate technology, which is sorely needed in view of the fact that the word "appropriate" has no semantic content in itself and begs the question "appropriate to what?" Appropriate Technologies therefore are those technologies which advance the objective of development, from which it follows that technologies

appropriate to rural development are those technologies which advance the objective of rural development.

Further, in view of the inter-dependence of rural and urban development (which was stressed in Lecture 1.1), it is obvious that the set of technologies appropriate to rural development consists of two sub-sets:- (1) appropriate rural technologies established in rural areas and (2) urban technologies appropriate to rural development. The second sub-set, i.e., urban technologies, must be included because the development of rural areas cannot be accomplished in an isolated and self-sufficient manner, but will require many inputs of critical materials, tools and equipment which must come from metropolitan centres. In this sense, an integrated steel plant or a ball-bearings factory is a vital component of rural development. In this course, however, attention is being focussed on the first sub-set, viz., appropriate rural technologies.

Comparison with other Definitions of Appropriate Rural Technology

This view of appropriate rural technology according to which it is linked to the development process can now be compared with four other approaches which are current, viz., the area approach, the factor-endowment approach, the resource-endowment approach, and the target-group approach.

According to the area approach, appropriate rural technology is technology which is appropriate to the rural area/region of interest, i.e., to the village, cluster of villages, or district. Such an area-based criterion of appropriateness ignores the fact that rural societies are stratified and that, while particular technologies can be appropriate to the region in which a rural society lives, their benefits may flow overwhelmingly to the richest and most powerful sections of that

society, and thus amplify its inequalities. Since such an impact negates rural development, it means that what is appropriate to a rural area may not necessarily be appropriate for rural development.

The factor-endowment approach is based on the view that appropriate technology is technology which is appropriate to the factors of capital and labour which the area is endowed with, so that in a capital-short, manpower-rich country, the technologies will be capital-saving and labour-intensive. While such an approach ensures employment-generation and manpower utilisation, it ignores the product-mix question, i.e., what mix of goods and services are produced and whether such a mix satisfies the basic needs of the neediest. Since it is easy to imagine luxury goods for the elite in poor countries and/or for export to the rich countries being produced in a capital-saving labour-intensive way, it is clear that the factor-endowment approach leads to an important part of the definition of appropriate technology, but not to a complete definition consistent with development. In other words, technologies can be appropriate to the country's endowments of capital and labour, but inappropriate for development.

The limitations of the resource-endowment approach are similar. While technologies appropriate for rural development must as far as possible be based on local resources, it is quite possible that technologies attuned to resources can be inconsistent with development because, for instance, the manner of production is not appropriate to the capital-labour endowments or the products which are produced are irrelevant to the neediest sections.

The emphasis on what products are produced and whose needs they satisfy is therefore of fundamental importance. This emphasis is safeguarded in the target-group approach according to which appropriate rural technology is technology which is

appropriate to the needs of the under-privileged sections of rural society. This target-group approach comes closest to the development-oriented definition of appropriate rural technology proposed above, but unfortunately it facilitates a narrow and short-sighted view in which remote and long-term linkages to the basic needs of the target groups are ignored. For instance, exclusive concern with the immediate needs of the weakest sections may lead the absence or insufficiency of attention on basic goods and infrastructure, e.g., steel, transport and power. Thus, the weakness of the target-group-based definition of appropriate technology is that it may restrict the time-horizon over which appropriateness should be considered. In contrast, the development-based definition of appropriate technology not only facilitates a balanced concern over long- and short-term development objectives, but also protects the interests of the target group by its emphasis on "starting from the needs of the neediest".

Misconceptions regarding Appropriate Technology

A vast number of misconceptions regarding appropriate technology are in circulation - in fact, some counterfeit versions have been deliberately propagated. These distortions will therefore be refuted here by the following series of assertions.

Appropriate technology is not against industrialization or against "modern" technology. It is for those products, patterns and forms of industrialization which will advance development in sense defined above. It demands a careful scrutiny of the economic, social and environmental implications of "modern" technologies from the standpoint of the objectives of development, and an unqualified acceptance of such of these technologies (in original or adapted forms) which advance those objectives. It rejects the blind faith that all the technologies of the developed countries are universally

appropriate, despite the specificity of the historical circumstances which spawned them and the particularity of the demands in response to which they were evolved. Also discarded is the naive belief that these technologies are always an unmitigated blessing, equally satisfying the interests of those who sponsor, hawk and vend them, as well as the development objectives of developing countries.

Appropriate technology does not represent a return to traditional technologies. However optimal traditional solutions may have been in the past, the emergence of new conditions, constraints, materials and needs have eroded that optimality and rendered it invalid today. But, this does not mean that traditional technologies cannot undergo qualitative transformations through minor modifications brought about by the use of modern science and engineering to understand and clarify the rational core of ancient practices. Such transformed traditional technologies may constitute a rich source for appropriate technologies.

Appropriate technology is not restricted to production, hardware and industry; it also involves products software and all sectors such as agriculture, health, communication, etc.

Appropriate technology is not primitive/low technology. To label it as such represents a gross confusion over criteria - the criterion of advanced/primitive or high/low should be based on the quality of scientific and engineering thinking underlying a technology, and not on its simplicity, or its geographical origin or the scale of production it involves. Thus, appropriate technology can be advanced/high technology.

Appropriate technology, therefore, does not imply under-emphasising basic research; in fact, it implies an even greater stress on basic research because, in the absence of a beaten (western) path to the new technologies, there is no alternative to falling back on fundamentals and new insights.

Appropriate technology is not concerned only with the smallest-scale technology. Since there is no universally valid inverse correlation between appropriateness and scale, small may not always be beautiful. For every product or service, there is likely to be an optimum scale or size (which can be small, medium or large), below which appropriateness increases with scale or size, and above which it decreases with scale or size. Appropriate technology, therefore, is concerned with optimum-scale technology.

The relationship between appropriate technology and "intermediate" technology cannot be defined because it has never been clear whether the term "intermediate" refers to a stage of industrialization (neither the most primitive nor the most modern), or to a scale (neither the largest nor the smallest). If, however, "intermediate" technology refers to the attempt to dump on developing countries all the machines used by industrialized countries in an earlier stage of their growth, then appropriate technology is not intermediate technology.

Appropriate technology is not a foreign concept. Several Indian thinkers have contributed to the formulation and elaboration of the concept of appropriate technology. If, despite this, the popularity of the book "Small is beautiful" has led to an impression that appropriate technology is a foreign concept, we have one more example of an indigenous idea acquiring legitimacy and respectability when it appears to come from the west - hence, one more instance of our cultural dependence which is a residue of a colonial past.

Appropriate technology is not merely a new manoevre of the developing countries. But, there is a manoevere afoot, and it consists mainly of (1) restricting the concept to small-scale, labour-intensive technologies for the Rural sector, (2) excluding large-scale, capital-intensive technologies,

and in fact, urging developing countries to under-emphasise these technologies whilst concentrating only on rural development, and (3) dominating the generation of appropriate technologies and the sale of the associated hardware and software. The response to this manoevre should be based, firstly, on the inseparability of the definition of appropriate technology from the objective of comprehensive development - of not only rural development -, and secondly, on the strengthening/ national capability for the selection and generation of appropriate technology so that these two processes (of selection and generation) are achieved in the developing countries by the developing countries for the developing countries.

Appropriate technology is not a substitute for the socio-economic changes crucial for real development, but it is the necessary technological component of these changes. Thus, it is a necessary condition for development, but not a sufficient condition - the socio-economic framework and the political structure must also be committed to development.

Appropriate technology is not pointless within the present framework of society but it will become so if attempts to choose, develop and diffuse appropriate technologies do not become an integral part of the struggles for real development.

Above all, appropriate technology is not a matter of expendiency, a transitory measure and a temporary device to cope with the current predicament of developing countries, particularly their problems of unemployment. It is an instrument of real development, in which social participation and control, and harmony with the environment are as important as the satisfaction of basic material and non-material needs. Thus, it is not a mere tactic, but a vital component of a new strategy; it is not a short-cut to old delusions, but a crucial part of a new vision; and it is not a short-term means to the goal of a consumption-obsessed western type society, but it is an inescapable path to a new society. 1.2.1(b)

Aspects of Appropriate Rural Technology

There are three fundamental aspects of appropriate rural technologies:

(1) their selection or choice,

(2) their generation or development, and

(3) their diffusion or dissemination.

These three aspects should all be interlinked in the sense that each should influence and be influenced by the others as shown in Figure 1. Attention will now be turned to a detailed discussion of the selection, generation and diffusion of appropriate rural technologies.

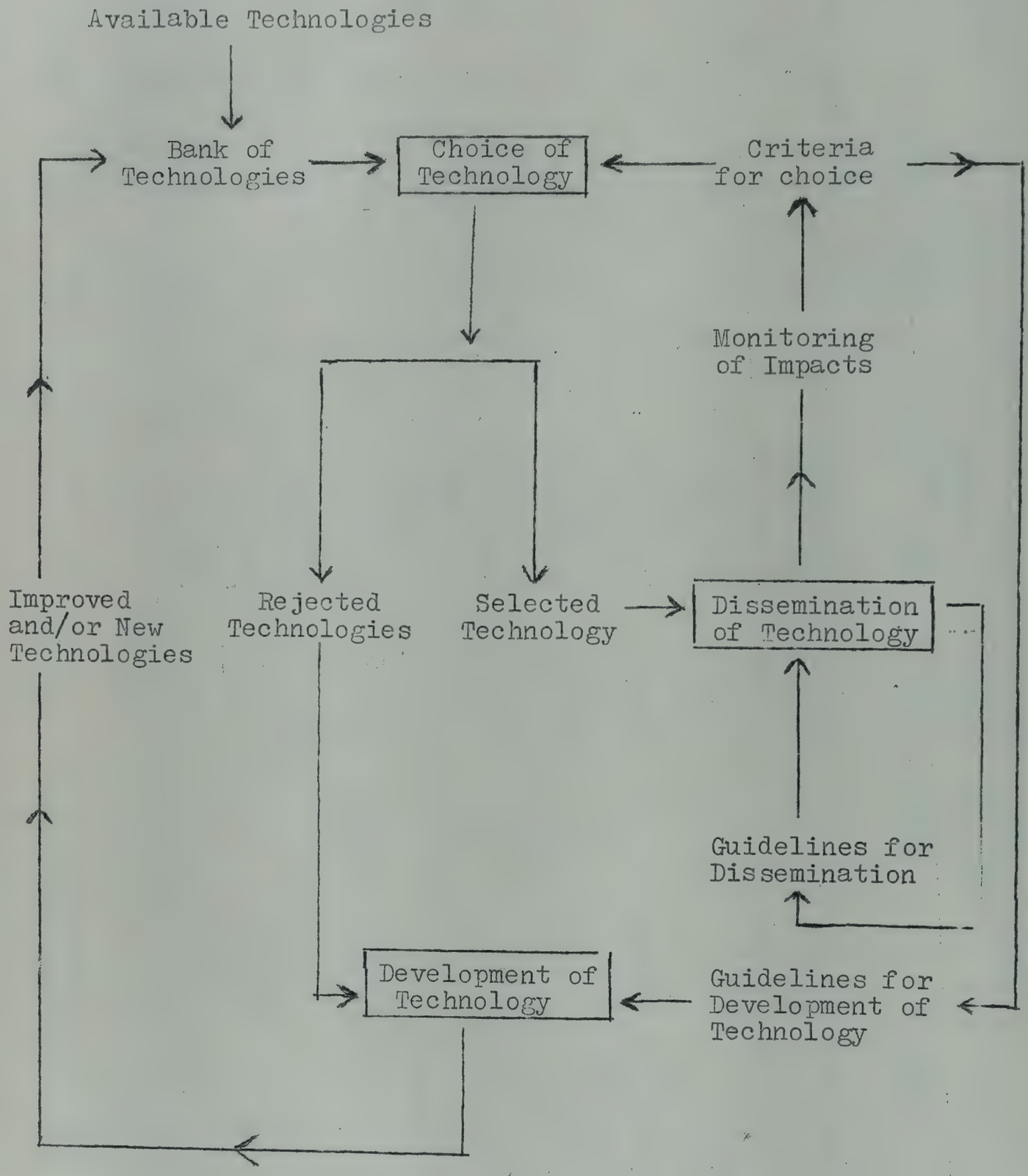
TABLE 1 : INVESTMENT AND EMPLOYMENT IN VARIOUS INDIAN INDUSTRIES

Sl. No.	Industry	No. of firms studied	Total Employment	Investment in machinery (Rs.in lakhs)	Employment co-efficient (Employment per Rs.100000 investment.	Rs.invested per job
1.	Cement	7	7,675	3,676.34	2.1	48,000
2.	Automobile Tyres & Tubes	2	3,720	2,617.00	1.4	71,000
3.	Fertilizers	2	4,405	15,850.00	0.3	3,33,000
4.	Tractors	1	1,140	213.00	5.4	19,000
5.	Heavy Electrical Equipment	1	52,000	16,000.00	3.3	30,000
6.	Storage Batteries	1	1,610	264.00	6.1	16,000
7.	Machine Tools	All units	45,000	11,000.00	4.1	24,000
8.	Commercial Vehicles	2	12,030	2,295.00	5.2	19,000
9.	Dry Cell	3	900	195.00	4.6	22,000
10.	Paper and Paperboard	1	3,500	6,000.00	0.6	1,66,000
11.	Agricultural implements	All units	2,000	400.00	5.0	20,000
12.	Electronics	3	44,180	4,640.00	9.5	11,000
	Total:		1,78,160	Total Rs.631.5 crores		

Source: For serial No.1 to 11 : Directorate General of Technical Development, New Delhi.
For serial No.12: Information, Planning & Analysis Group (IPAG), Electronics Commn., New Delhi.

Notes:
1. A total investment of Rs.631.5 crores with above pattern has created 1,78,160 jobs, i.e., Rs.35,440 per job.
2. On this basis, provision of employment for (a) the back-log of 20 million unemployed would require an investment of Rs.70,000 crores, (b) the 5 million new entrants to the work force every year would require Rs.17,500 crores.

Figure 1. Inter-relationship between choice, development and dissemination of appropriate rural technology



SELECTION OF APPROPRIATE RURAL TECHNOLOGIES

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Lecture 1.2.2
Rural Technology Course

SELECTION OF APPROPRIATE RURAL TECHNOLOGIES

Amulya Kumar N. Reddy

Sources of Appropriate Rural Technology

At the outset, it is necessary to list the possible sources of technology. In fact, seven possible sources can be listed: three sources "external" to the country, and four "indigenous" sources. The technologies from "external" sources consist of

(1) "western" technologies from the industrialized countries,

(2) technologies from other developing countries, which invariably turn out to be "blurred xerox copies" of western technologies, because of the usual imperfections in the process of import, imitation and adaptation, and

(3) what are recommended by the developed countries nowadays as "appropriate" technologies in view of their apparent concern for the appropriateness of technologies which are sought to be transferred.

The technologies from "indigenous" sources consist of

(1) traditional technologies, which have been evolved over centuries by a process of natural selection of innovations,

(2) transformed traditional technologies, which are based on inputs into traditional technologies of the rich heritage of scientific and engineering knowledge, research materials or techniques,

(3) alternative technologies, which are specifically designed ab initio for appropriateness;

(4) naturalized technologies which are based on the import, imitation, adaptation and domestication of western technologies.

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Appropriate Rural Technologies - a Dynamic Mix

None of the above sources must be excluded from the process of selecting appropriate rural technologies. There should neither be an automatic rejection of all traditional technologies, nor should there be an over-reaction that all western technologies are ipso facto inconsistent with development. Whereas the total pattern of western technologies may be inappropriate for development, there may be many specific technologies which may be eminently appropriate. Hence, it is obvious that the set of appropriate rural technologies is likely to be a mix from the various sources. Further, since the precise shape of development objectives will change with time, it is likely that the mix also will change with time, i.e., the mix is likely to be dynamic.

The real problem, therefore, is to decide the mix of technologies from various sources, which in turn reduces to the problem of deciding whether a particular technology is appropriate or not. In other words, what is required is a method of selection of appropriate rural technologies. There are two crucial aspects of this methodology:- (1) the criteria to be used, and (2) the procedure for using these criteria.

The Importance of Criteria of Appropriateness

It must first be stressed that the criteria used in the choice of technologies are important for several reasons.

(1) When criteria are explicitly stated, they have to be reckoned with, and this enforced reckoning tends to counteract arbitrariness in policy-and decision-making.

(2) The spelling out of criteria facilitates their publication. Also, the more broadcast an awareness of the criteria, the less the risk of their being ignored in policies and decisions; and when they are ignored, the greater the consciousness that this is being done, and the greater the need for an open justification of the omission, deletion or

suppression of criteria. Hence, criteria have an impact both on policy-makers and decision-makers, and on those who are affected by policies and decisions. From this point of view, the purpose of setting down criteria is to be broaden the base of policy- and decision-making.

(3) An increase in awareness of the criteria to be used in the choice of appropriate technologies will, on the one hand, generate a widespread demand for such technologies, and on the other hand, guide those who generate technologies. The significance of this conscientization of scientists and engineers must not be underestimated, because the definition and appreciation of criteria is an inhibiting factor against the development of inappropriate technologies.

(4) Notwithstanding the obvious importance of establishing criteria for the choice of appropriate technologies, it is interesting that no explicit list of criteria exists today. This only means that the criteria are usually implicit. Nevertheless, even implicit criteria can be deciphored from the technologies in vogue and from the decisions that ushered in these technologies. And, if many of these technologies are inappropriate, then it follows that the explicit statement of criteria is a vital step in generating and adopting appropriate technologies.

In so far as criteria must be derived from objectives, the criteria for the choice of appropriate technologies must emerge from development objectives indicated in Lecture 1.1. This is undoubtedly a normative approach to the definition of criteria. The approach is based on the following value judgements:-

(1) that economic development, particularly of rural areas, is an urgent objective of the highest priority;

(2) that, in the ultimate analysis, it is a basic need of human beings to participate in the decisions and processes concerning their destiny and to exercise increasing control over these decisions and processes;

(3) that the environment is the sole irreplaceable habitat of man and must therefore be jealously protected and husbanded.

Criteria of Appropriateness

Stimulated by such a perspective, a first-approximation attempt to identify criteria consists of the following statement of a list of preferences to be used in the choice of technology.

The economic dimension of development requires the exercise of preferences for technologies which are need-based, rather than demand-oriented, and which reduce, rather than amplify, inequalities between rural and urban areas and within rural areas, for example,

(1) A preference for technologies which are consistent, rather than incompatible, with the basic resource endowments, which means, for most developing countries, a preference for energy-conserving, capital-saving and employment-generating, rather than energy-extravagant, capital-intensive and labour-saving, technologies;

(2) A preference for the technologies of goods and services relevant to mass consumption, rather than to individual luxuries;

(3) A preference for technologies based on local materials, rather than materials which have to be imported from abroad or transported from distant parts of the country;

(4) A preference for technologies which generate employment for underprivileged masses, rather than for privileged elites;

(5) A preference for technologies which produce for local consumption, rather than for remote markets;

(6) A preference for technologies which promote a symbiotic and mutually reinforcing, rather than parasitic and destructive, dependence of the metropolises of developing countries on their rural hinterlands.

The social dimension of development necessitates the exercise of preferences for technologies which promote indigenous local self-reliance by increasing social participation and control, for example,

(1) A preference for technologies which lead to an enhancement of the quality of life, rather than merely to an increase in the consumption of goods;

(2) A preference for production technologies which require satisfying creative work, rather than boring routine labour, i.e., for technologies which relate human beings to work, rather than alienate them from it;

(3) A preference for production technologies in which machines are subordinated to, rather than dominate, the lives of people;

(4) A preference for technologies which lead to human settlements being designed to suit the collective and individual lives of people, rather than the requirements of agglomerations of productive units;

(5) A preference for technologies which promote ease, rather than sophistication, of operation;

(6) A preference for technologies which blend with, rather than disrupt, traditional technologies and the fabric of social life;

(7) A preference for technologies developed indigenously from the local context, rather than transferred from alien settings;

(8) A preference for technologies which facilitate the devolution of power to the people, rather than its concentration in the hands of elites.

The environmental dimension must be concerned with the rational sustained use, rather than indiscriminate rapid devastation, of the resource-bestowing and life-supporting bio-geophysical environment. Hence, this dimension must involve, the exercise of several preferences in the choice of technologies, for example,

(1) A preference for energy-production technologies based on renewable, rather than depletable, energy sources (e.g., sun, wind and biogas, rather than oil or coal);

(2) A preference for resource- and energy-saving, rather than resource- and energy-intensive, technologies;

(3) A preference for technologies which produce goods that can be re-cycled and re-used , rather than used once and thrown away, and that are designed for durability, rather than obsolescence;

(4) A preference for production technologies based on raw materials which are replenishable (e.g., wood and cotton), rather than exhaustible (e.g., steel or petroleum-based synthetic fibres);

(5) A preference for technologies of production and consumption which inherently minimise noxious or dangerous emissions and wastes, rather than those which require 'fixes' to curb their intrinsically polluting tendencies;

(6) A preference for technologies of production and consumption which incorporate waste minimization and utilization procedures as integral components, rather than those which require them as appendages;

(7) A preference for technologies which blend into natural ecosystems by causing them minimal disturbance, rather than those which threaten the biosphere with major perturbations.

Since every preference implies a criterion and, indeed, can be re-phrased as a criterion, the above list of preferences are in fact a set of criteria for the choice of appropriate technologies. For example, the "preference for the technologies of goods and services relevant to mass consumption, rather than to individual luxuries" can be stated as the criterion: "Does the technology produce goods and services which are within the means or the masses?" Or, the "preference for energy-production technologies based on renewable, rather than depletable, energy sources" can be transformed into the criterion: "Is the energy production technology based on renewable energy sources?

An obvious shortcoming of a set of criteria as large as the one presented above is that it is likely to inundate - and perhaps confuse - even the makers of policies and decisions, let alone laymen. Further, after a choice of technology has been made, it will not be easy to detect whether one or more criteria have been omitted, deleted, suppressed or ignored. On the other hand, the large set has rightly elaborated upon and made explicit the crucial economic, social and environmental dimensions of development. The conclusion is that a list of explicit criteria is vital for selecting technology, but the list must be much shorter, more manageable and less complex.

Of course, the other extreme is a very short list which can be generated naturally from the definition of development objectives, i.e.,

(1) Does the technology advance the satisfaction of basic human needs, starting with the needs of the neediest; and does it reduce inequalities between and within countries?

(2) Does the technology promote indigenous self-reliance through an increase of social participation and control?

(3) Does the technology increase harmony with the environment?

This list is obviously far too brief to facilitate detailed interpretation and unambiguous use.

What is required, therefore, is a short list with some number of criteria in between three and twenty nine. It should be neither too brief and vague, nor too long and cumbersome. The list should be compact, and preferably presentable on a single page. One such list is presented here.

CRITERIA FOR THE SELECTION OF TECHNOLOGY

(1) SATISFACTION OF BASIC NEEDS

(a)--does the technology contribute to the satisfaction of basic needs such as food, clothing, shelter, health, education, etc.?

(b)--does it produce goods and/or services accessible particularly to those whose basic needs have been least satisfied?

(2) RESOURCE DEVELOPMENT

(a)--does it make optimal use of local factors (manpower, capital, natural resources, etc.) by

(a) sustaining/generating employment;
(b) saving/generating capital;
(c) saving/generating raw materials, including energy;
(d) developing skills and R & D and engineering capabilities?

(b)--does it increase the capacity to produce on a sustained, cumulative basis?

(3) SOCIETAL DEVELOPMENT

(a)--does it reduce debilitating dependence and promote self-reliance based on mass participation at the local levels, enabling the area to follow its own path of development?

(b)--does it reduce inequalities?

(4) CULTURAL DEVELOPMENT

(a)--does it make use of and build on indigenous technical traditions?

(b)--does it blend with/enhance valuable elements and patterns in the local culture?

(5) HUMAN DEVELOPMENT

(a)--does it lead to creative mass involvement by being accessible, comprehensible and flexible?

(b)--does it liberate human beings from boring, degrading, excessively heavy or dirty work?

(6) ENVIRONMENTAL DEVELOPMENT

(a)--does it minimize depletion and pollution by using renewable resources, through built-in waste minimization, recycling and/or re-use and blending better with existing eco-cycles?

(b)--does it improve the natural and man-made environment by providing for a higher level of complexity and diversity of the eco-systems, thereby reducing their vulnerability?

The list of six criteria (each in turn being subdivided into two, making in all twelve) may well be the first of its kind, but it is certainly not proposed with any aura of finality. In fact, it is in the nature of such lists that they generate more controversy than consensus, but that is as should be, for it is by a process of contention and testing that their revision and refinement will take place.

The tentative list proposed here is based on a condensation of the long list of 29 criteria and on an elaboration of the three basic development criteria. The list covers economic, social and environmental criteria. No attempt will be made here to provide a detailed justification for the items in the list, because they are based on the conceptual framework for appropriate technology, dealt with earlier.

Aspects of One-page Criteria List

It is obvious that there is a great deal of overlap in the list of six criteria described above. The criteria are not exclusive, and one criterion may involve another through close interaction. This is inevitable, because the economic, social and environmental aspects of development are interrelated and, in fact, components of a single process.

In so far as the process is the reality, and its resolution into components is an analytical device, the criteria must be considered together as an integral set. Thus, the strong coupling between criteria necessarily requires a holistic, rather than piecemeal or sectoral, approach to the choice of appropriate technology.

Such a holistic set of criteria - of the type described above - has not been proposed hitherto. There may be several reasons for this lacuna, but one cannot ignore the fact that excessive specialization and professionalization have led to

such divergent approaches of the economic, social and environmental disciplines that a common language for trans-disciplinary discussions is difficult to maintain. Yet, it is precisely such an integrated approach which must be taken to the selection of technologies designed to serve development goals, because development itself is a unified process, albeit with economic, social and environmental facets. In other words, the economic, social and environmental categories of criteria must inter-lock and converge to promote development.

Hence, any methodology which excludes one or more criteria from explicit consideration must be viewed as ipso facto misleading, however rigorous it may appear. In particular, this statement refers to methodologies which only confine themselves to the quantifiable criteria because some of the criteria, e.g., those relating to self-reliance or human enrichment, may be inherently non-quantifiable.

The six criteria constitute, an extremely demanding and exacting list. Hence, an obvious objection to the list is that few technologies will satisfy all criteria, making the whole travail a worthless exercise. Such an objection is indeed tenable, if the criteria are interpreted in a passive, static manner, in which selection is made from a set of existing technologies, and the issue is then closed. But, the objection subsides if the criteria are used in a dynamic perspective as a heuristic leading to the generation of new technologies. Thus, at any one time, few technologies may satisfy all the criteria, and there may always be scope for improving them even if they do. But, the testing of technologies against the criteria will reveal reasonably clear guidelines for innovation and modification. From this standpoint, the list of criteria is a long-hoped-for yardstick for the innovation of appropriate technology.

The obvious implication of the above discussion is that, until the new or modified technologies make their appearance, the best has to be made of the "bad bargain" of existing technologies. This can be done by weighting the criterion and settling for trade-offs amongst them. There should be little objection to such choices based on weights and trade-offs as long as all the criteria are explicitly and seriously considered and the processes of weighting and trading-off clearly revealed. But perhaps what is of greater importance is that efforts should be mounted to generate new technologies which allow all criteria, or a greater number of them, to be satisfied at the same time and which lessen the extent of trade-offs. In fact, since most choices of technology imply trade-offs between criteria, and since most currently available technologies have been developed without reckoning with a set of criteria of the type proposed here, it is likely that more attention will have to be paid to the generation of new technologies than to the choice between existing ones. Thus, the selection and generation of technologies constitute a dialectical unity, either one implying the presence of the other and being meaningless in the absence of the other. In particular, the selection of technologies has little meaning unless set in the context of the generation of technologies.

To state the issue differently, it is almost certain that, from the standpoint of the list of criteria proposed here, few current technologies are perfectly appropriate. It is only a matter of some technologies being more appropriate than others. But, the revelation of the gap between the ideal and the actual provides the motivation for attempting to narrow the gap, i.e., for increasing the appropriateness of technologies. In so far as the list of criteria has revealed both the goal of appropriateness, as well as how far away from the goal current technologies are, the list may be viewed as a distinct step forward.

Assessment of Technologies vis-a-vis Criteria

Since development is a process which depends upon an integration of economic, social and environmental activities, the selection of technologies to advance development objectives must be based on an integrated use of economic, social and environmental categories of criteria. The exclusion of any one or two categories of criteria may well lead to a choice of technology, but such a selection is only likely to distort the development process because crucial aspects of this process are ignored.

All this means that the technologies contending for selection must be assessed against a total set of criteria of the type set down above.

Sequential Use of Criteria

One possible approach to this assessment is the sequential approach which involves using the criteria in a sequence one at a time and assessing all technologies against each criterion. Thus, the approach is to take the whole set of candidate technologies, to pass them through what may be called "decision filters", each filter representing one criterion, and to eliminate at each stage those technologies which fail to survive the criterion.

Unfortunately, such a sequential elimination of technologies suffers from a number of drawbacks. Firstly, the criteria are such that they do not permit a sharp pass/fail judgement; the result of the test is often unclear, making the elimination process very difficult and awkward. Secondly, a particular technology may just get rejected out by, say, the second criterion in the sequence even though from a total point of view it may be more appropriate than a technology which just scrapes through all filters. Thirdly, the sequencing of criteria encourages the decomposition of the

total view represented by the whole set of criteria into narrow, specialized, discipline-based viewpoints. The situation can be caricatured by imagining that the responsibility of wielding different criteria is allocated to different agencies, say, different ministries. Finally, the sequencing of criteria confers a great deal of significance to the particular order in which the criteria are arranged. A different arrangement may lead to the selection of a different technology. The way to guard against this possibility of non-commutativity of decision filters, i.e., different arrangements giving different results, is to finalise the selection of technology only after trying out all possible sequences. But, the larger the number of criteria, the larger the number of possible arrangements, e.g., 720 possible arrangements with 6 criteria.

The technology profile approach

Not only does the last-mentioned criticism of a sequential use of criteria indicate a ridiculous situation, it also suggests an alternative approach. Instead of assessing all technologies against criteria taken one at a time, the alternative approach involves using all criteria against technologies taken one at a time. That is, instead of a sequential decision-making on technologies, the alternative is to postpone the decision of selection until each technology in turn is scrutinized with the aid of the entire set of criteria. Such a scrutiny will result in an assessment or profile for each technology, which describes the extent of its appropriateness. Only when the profiles of all the contending technologies have been made and compared with each other, can the process of selection proceed further.

In arriving at such technology profiles the application of some criteria, especially the economic ones, can yield quantitative answers, i.e., numbers. Referring to the answer

resulting from the application of a criterion as an attribute of the technology, it follows that every technology has some quantitative attributes. However, there are other criteria, for example, the social criteria, which yield answers that are not easily quantifiable, or have not yet been quantified - these correspond to the not-easily-quantifiable attributes of a technology. The question arises as to how to treat these latter attributes of a technology. In this context, it must be realized that even in the case of criteria that do not generate quantitative answers, it is almost always possible to judge whether the technology under scrutiny can be rated qualitatively as "acceptable", "unacceptable" or "ambiguous" from the standpoint of the particular criterion. Thus, every criterion in the list can be made to yield either a quantitative or qualitative judgement.

Further, the whole list of criteria will generate, for each contending technology, a profile consisting of a set of as many component judgements as there are criteria.

The Representation of Technology Profiles

There may be various ways of presenting such profiles and set of judgements, but a simple method involves a bar-chart display.

	1		2		3		4		5		6	
TECHNOLOGY	a	b	a	b	a	b	a	b	a	b	a	b
1	G	G	x_{11} • • x_{1n}	y_{11} • • y_{1n}	O	N1	R	R	O	O	G	R

G = Green O = Orange R = Red N1 = See Notes 1

In such a display, the profile for a particular technology is represented by the whole bar, which can be divided into segments, with one segment for each criterion or sub-criterion. Also, the segments can be numbered in the same way as the criteria are

numbered in the list proposed for selection of technology. Further, the rating of the technology with reference to each criterion can be indicated within its corresponding segment. This indication can be shown either with numerical information (or references to appended notes) if the segment corresponds to a quantitative criterion, or with a simple colour code - for example, green for "satisfactory", orange for "ambiguous", and red for "unsatisfactory" - if the segment represents a criterion which only permits qualitative judgements on the technology.

In so far as some criteria permit quantitative judgements, and others only qualitative ones, it follows that the profile for a technology will inevitably consist of a mix of quantitative and qualitative components, and the corresponding bar-chart representation will have numbers in some segments, and colours in others.

Profiles involving such mixes of quantitative and qualitative components are unavoidable. Or rather, mixes can be avoided today only by suppressing those criteria, e.g., the self-reliance one, that do not yield quantitative answers. But biases of this type against non-quantitative criteria will only lead - as already stressed - to the selection of technologies which distort development objectives because they eliminate some of its vital dimensions.

On the other hand, however unconventional they may be, profiles of the mixed type described above have an outstanding virtue - they always include judgements with respect to all criteria. This advantage of totality of view is a recompense for the qualitativeness of some aspects of the composite view. Further, by stimulating a holistic assessment of each technology, these profiles prevent rigorous quantitative judgements on a few criteria from blinding the assessment to the fact that other criteria have been completely ignored. In the bar-chart

representation, judgements are indicated (either with numbers or colours) in all the segments, so that if any criteria are ignored, the corresponding segments will remain blank, and therefore attract instant attention. Also, these empty segments will immediately reveal the incompleteness of what would otherwise appear as a highly sophisticated and rigorous assessment of the technology.

The question of quantification and quantifiability

Because qualitative judgements must not ipso facto be given a lower standing in the technology profile than quantitative ones, it must not be concluded that the attempt to quantify should be either abandoned or downgraded. Whatever can be quantified, must be quantified; and whatever quantification can be done more precisely and rigorously, must be done more precisely and rigorously. In other words, there must be a continuous drive to replace colours with numbers in the bar-chart representation for a technology profile.

One approach to quantification is through the construction of attribute utility functions. Considering a particular attribute, e.g., capital cost, a range of values of the attribute is chosen so that its lowest value is assigned a preference or utility of 1 and its highest value, a preference of zero. If the capital costs corresponding to preferences of, say, 0.75, 0.50 and 0.25 are also obtained, then an attribute utility function is obtained with the utility (or preference) plotted as a function of the value of the attribute.

Another important way of assessing a technology is to measure, wherever possible, the physical transformation of inputs into outputs. Such measurements are very significant, because the input-output relationships indicate the impact of the technology. Hence, an accurate knowledge of these transformation relationships constitutes an invaluable element of the technology selection process.

A number of techniques exist for manipulating these measurements towards an assessment of technologies, and amongst them is cost-benefit analysis, which is the most widely used quantitative technique. It has a positive role to play in technology selection, and therefore, merits a brief discussion, even though it is only one amongst many techniques which can be used to set out the basic measurable parameters.

Cost-benefit Analysis

In essence, all decisions are based on the weighing of benefits (material and/or non-material) against costs. Further, in all cases, the concept of time-preference is involved, since the distribution of these costs and benefits over time will have some bearing on the decision. Also relevant to the decision are the questions of risk and uncertainty. Cost-benefit analysis is designed to reflect all these elements, viz., costs and benefits, time-preferences, and risks and uncertainties.

However, there are a number of problems associated with the use of this technique.

The first is that of so-called externalities, be they economic (e.g., the impact of a large project on local wage rates), social (e.g., the displacement of a community in the construction of a dam) or environmental (e.g., pollution of rivers), i.e., externalities as seen from the viewpoint of a particular project, plant or enterprise. From the point of view of society, however, these impacts are no less "internalities" than various factors, e.g., labour productivity, which are deemed "internalities" by the project, plant or enterprise. To include all these impacts in the reckoning, it is necessary to use social cost-benefit analysis, which attempts to cope with these externalities by the use of shadow prices. But, these shadow prices are only approximations and/or proxies, and

often lend themselves to such arbitrariness that the cost-benefit analyst can produce any result that his sponsor or patron (usually the politician) wants, or that his own social conditioning and/or vested interests bias him towards.

This suggests the second limitation of cost-benefit analysis, viz., it is so attracted by numbers in trying to reach the mirage of quantitative results that it tends to exclude from the analysis all or most non-quantifiable factors (such as the loss of communal solidarity when the population displaced by a dam is moved to a new environment), even though these latter factors may be as relevant to development than the quantifiable factors.

A third limitation of the technique is that it requires a decision with regard to how far the net of analysis is to be spread. Second-round effects may be considered, but are third-round effects to be considered, if, in fact, they can be identified?

Fourthly, there are the very real problems of risk and uncertainty. There may be some uncertainty with regard to the effect of a particular project on the environment, or there is a risk that the expected outcome may not occur in the predicted way. Both of these factors undermine the precision of cost-benefit analysis.

Fifthly, there is the very real danger that the technique can be manipulated in such a way as to rationalise decisions reached for other reasons.

Finally, a very important drawback of cost-benefit analysis is that it assumes that unlike things (such as apples and oranges) can be compared with a constant unit of measurement, and that equal differences on the scale of cardinal measurement have the same significance, e.g., the difference between ten and eight has the same significance as the difference

between four and two.

The level at which such an analysis is undertaken is also of great importance, since by its nature it is much more suitable to micro- than to macro-problems. Further, it is possible to undertake an analysis with data of a very 'soft', or very 'hard' nature, and this will determine the degree of trust to be placed in the analysis. Both of these aspects follow from decisions made before cost-benefit analysis is undertaken.

Notwithstanding these limitations of cost-benefit analysis, it has an important role in quantifying the judgements with respect to some of the criteria relevant to the selection of technology. The important thing is that the technique should be used in an unjaundiced ex-ante framework, rather than as an ex-post rationalizing, where spurious quantification is undertaken in order to justify a decision taken on other grounds. There are two other main advantages to be derived from the use of cost-benefit analysis. The first is that it forces the systematic quantitative consideration of a number of criteria, and the second is that the technique serves as an heuristic device with regard to quantification of other as-yet-unquantified criteria.

The above discussion shows that the constant drive for quantification of judgements, for example, using cost-benefit analysis, though absolutely essential and imperative, must be tempered with a clear appreciation of its current drawbacks and limits. However, there is a time element here. Today, the profiles for technologies may necessarily consist of mixes of quantitative and qualitative judgements; but, future innovations in analysis may well confer a quantitative character on judgements which are now perforce qualitative.

Once profiles are built up for all the various contending technologies, the next step is to compare these profiles in order to make a selection of the most environmentally sound and appropriate technology. The comparison is facilitated by the bar-chart representation. What is required is an arrangement of the representations of the profiles of all the contending technologies, so that the juxtaposition highlights the differences between the technologies as differences in either magnitudes of numbers (in the case of quantitative criteria) or colours (in the case of non-quantifiable criteria). It is these differences which must provide the basis of the selection of the most appropriate technology.

The simplest, but rather unlikely, situation involves a technology which is superior to the others on all counts. Here, selection is a straight-forward matter. Slightly more complicated is a ceteris paribus (other things being equal) situation in which the contending technologies differ only with respect to one criterion, but are otherwise equally appropriate. In such situations, the deeper the analysis with respect to the particular criterion that generates differences, the easier the selection procedure. And when the criterion permits quantitative differences, the situation is particularly suitable for cost-benefit analysis.

The problem of weighting criteria and making trade-offs

The real problem, however, arises when contending technologies differ with respect to two or more dissimilar criteria, but are otherwise just as appropriate. For example, one technology may have a higher capital-output ratio, but the other stimulates much more self-reliance; or one leads to greater human enrichment, but the other is not only less polluting but also less depleting with regard to resources.

The essence of these very common situations is the necessity of choosing between impacts which cannot be compared.

In other words, the process of selection cannot avoid assigning weights to each criterion and making trade-offs. The technique of multi-attribute decision analysis permits a quantitative method of assigning weights and making trade-offs.

In terms of the bar-chart representation for technology profiles, the weight assigned to a particular criterion can be indicated by the length of the corresponding segment. Since, however, numerical weights cannot be assigned to non-quantitative criteria, little significance must be attached to the precise length of segments, though some idea of the relative weights may be given by the relative lengths of segments.

There may, in fact, be a subjective element in the relative weighting of criteria, but there should be no objection to such trade-offs as long as all the criteria are given explicit and serious consideration. For, there is a very important qualitative difference between, for example, ignoring completely the extent to which a technology facilitates self-reliance; and in contrast, taking the contribution to self-reliance into account, but giving it low weight, or giving it a high weight, but explicitly stating that the technology does not satisfy the self-reliance criterion. In the former case, the decision-making agenda does not even include the self-reliance item; in the latter case, it is on the agenda and compels attention, even though it may be given little emphasis in eventual trade-offs.

At the other extreme, there is room for making a particular criterion, e.g., employment generation, an absolute condition for selection in the sense that if it is not satisfied, the technologies under scrutiny are rejected. But, even here, the total profile for every contending technology must be considered and their other virtues noted.

The context and standpoint in decision-making

The weights attached to the various criteria, and therefore to the corresponding judgements in the technology profiles, are bound to vary with the historical, geographical, economic, social and environmental context, i.e., with where and when the technology selection is being made. In addition, the weights to the criteria, i.e., to the numbers and colours in the bar-chart representation of technology profiles, depend very much upon the individuals and groups who are involved in the assessment. Thus, a community which is displaced by a large dam may attach a totally different weight to the effect of a resettlement technology on their culture, i.e., to the cultural criterion, than a group of human settlements experts in a remote capital to whom the economic criteria, e.g., the costs of technology, are the crux of the technology selection issue. As stressed earlier, it is inevitable that different criteria are emphasised differently and that trade-offs are made, but what is essential is that the emphases and trade-offs are explicit and open.

Special participation in technology selection

Even this explicitness and openness does not guarantee that the most appropriate technology has been selected, for that is a matter that only the future can judge. But, the probability of a "correct" decision may be enhanced by ensuring the participation, in the selection process, of those directly involved in the implementation of the selected technology and of those who will be affected by the implementation of the technology. Even if this increase in probability is not achieved, the widening of participation in technology selection, particularly by the procedure of constructing, comparing and assessing technology profiles, will certainly increase the extent of economic, social and environmental consciousness. This conscientization is likely, not only amongst policy-makers, but also amongst scientists, engineers, technicians, and above all, the population at large. Technological consciousness is

bound to become more broad-based and generate demands not only on those who select technologies but also those who develop them, making these two groups more accountable in terms of the criteria discussed here.

The iterative process of technology selection

The comparison and assessment of technology profiles is not a "one-shot, once and for all" process. It must be dynamic in three ways.

Firstly, the selection that is made at any juncture must be viewed as tentative, rather than final. It should be considered as the "best" understanding of the possible effects of various contending technologies, rather than as the "correct" understanding. In that sense, technology selection is part of a social process involving technology-induced change. As the results of social change manifest themselves, they can be gauged from the standpoint of development objectives. This information can then be used to modify the technology profiles, particularly the profile of the technology which was selected. The point is that information on the actual effects of an implemented technology will reveal far more clearly (than theoretical expectations) how appropriate it is. If, therefore, the technology selection process is repeated, with actual, rather than expected, technology profiles, it is likely that a more realistic or assured selection can be made.

Secondly, the selection of technology has been stressed to be a heuristic device for the generation of new and/or modified technologies. This means that technology profiles will alter as a result of changes in the contending technologies. Not only the numbers corresponding to quantitative criteria, but also the colours corresponding to qualitative criteria, undergo transformations as a result of research and development. The well-known example is that of technologies with malignant environmental effects being made benign by inputs of science and engineering - in the bar-chart

representation of the profiles for these technologies, erstwhile reds can become orange or even green. The implication is that the results of the comparison of technologies will change because of R & D-induced changes in profiles.

Thirdly, the list of criteria proposed here are certainly not the last word. As experience with technology selection grows, and as understanding of the interplay of economic, social and environmental factors increases, it is inevitable that the list of criteria will be refined and improved. As a consequence of changes in criteria, the profiles which have been generated by these criteria will also undergo changes, necessitating new comparisons of contending technologies and fresh selections.

Thus, the selection of appropriate technologies must be an iterative process, with the iteration being compelled by

(a) improved information on the effects of implemented technologies, and/or

(b) the continuous influx of new or modified technologies into the arena of selection, and/or

(c) the refinement and improvement of the criteria for selection.

Problems of iteration

The iteration sequence can be as follows: tentative selection of technology ⟶ implementation of selection technology in society ⟶ study of impacts of technology ⟶ improved criteria and/or technologies and/or information on impacts ⟶ better selection of technology ⟶ .....

Real-time iteration may well be more acceptable, but it is associated with several problems:-

(a) technologies have a gestation time before they reach full effectiveness, and the larger the scale of technology, the

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larger the gestation time, which means that real-time iteration may be an agonizingly long process;

(b) technologies have a momentum of their own, for instance, because of the capital investments made in them, and the larger these investments, the more painful and unlikely the process of withdrawing technologies however environmentally unsound and inappropriate they may prove to be, and the stronger the tendency to live with technological "frankensteins";

(c) some impacts of technology require such long times to manifest themselves - e.g., environmental impacts may take decades - that, unless ingenious techniques of monitoring incipient trends are devised, it would be too late and futile to wait for real-time manifestations before taking corrective action;

(d) if the pace of technological advance is faster than the pace of the iterative selection process, then real-time iteration becomes virtually endless.

If, on the other hand, the iterative selection of technologies is done on simulated models of the society, then the validity of selection depends wholly on the validity of the model. It is a moot point whether the state-of-the art in model building justifies confidence in such an approach. There is, however, a possibility that a simulation approach to technology selection can be combined with real-time testing of short-gestation, low-momentum, small-scale technologies, but this may lead to in-built biases against large scale technologies.

In this context, it is important to remember that, even in the most advanced countries and even with the use of the most sophisticated techniques, monstrous technical mistakes have been made. The moral, therefore, is to proceed on the

assumption that decision-makers are certain to make mistakes, hence, let the mistakes be small, reversible ones, and for this condition to be realized, let the choices be increased.

Constraints on the Technology Selection Process

Before turning to a review of the methodology, the autonomy of the selection process must be discussed.

A consideration of production technologies cannot take place without a prior specification of the product or service. The point is that basic human needs are few in number and there is no sanctity, except native custom or foreign influence, to any particular bundle of goods and services which can fulfil these needs. For example, an element of sweetness may be necessary in the human diet. In all developed countries, and in the cities of most developing countries, crystallized white sugar is produced to satisfy this need. But, this is only one way, amongst many, of providing sweetness to the diet - other ways include jaggery, berries, artificial sweetners, etc. Hence, the sweetening agent must be decided upon before a selection can be made of a technology for producing it.

The distinction between product specification and selection of production technology generates an important question; is the product specification within the scope of the technology selection process, or is it externally imposed? The answer, of course, depends upon the autonomy of the selection process.

In turn, this autonomy depends upon the particular level - local, sub-national, national, regional - at which the technology selection takes place, and the relationship between this level and the higher/lower level.

Two cases can be distinguished.

In the first case, the level at which technology selection is being made is in a position to determine the product. Here,

the product specification is part of, and internal to, the technology selection process which, therefore, enjoys autonomy in this matter.

In the second case, technology selection is done at one level, e.g., the local level, but specification of the product is determined by a higher level, e.g., the national level. Here, the technology selection process is not autonomous in the matter of product specification, and the latter is imposed as an external constraint on the process.

Depending, therefore, on the extent of autonomy with regard to product specification, the selection process can be either free or externally constrained.

A similar situation can obtain with respect to the growth rate for products and services, i.e., the rate at which the production output is expected to change over the years. This growth rate has an important bearing on the selection of production technology and, therefore, the crucial question is whether the technology selection process enjoys the autonomy to decide the growth rate, or whether the latter is fixed as an external constraint at a different level.

The category of externally decided constraints which affects the technology selection process must also include certain macro-decisions regarding production technology. For example, there may be national decisions regarding the role of centralized, large-scale industries, and these decisions may circumscribe and limit the autonomy of the technology selection process at lower levels.

Just as a higher level can impose constraints on technology selection at a lower level, it can also happen quite frequently that technology selection at a higher level is vitiated by preferences and choices at a lower level. The reference here is

to the well known conflicts between a society on the one hand and classes, groups or households on the other. These conflicts are primarily over two issues:- (1) the present distribution of resources between different classes and groups and households, and (2) the time-distribution of resources between present and future generations. The second type of conflict, viz., between the present and the future, can be resolved through technologies which are compatible with a sustained use of resources over the long-run. The first type of conflict, viz., between different groups in society, can only be resolved politically, and if it is resolved in favour of satisfaction of the needs of the neediest, then it is a development-oriented technology selection leading to the choice of appropriate technology. If on the other hand, a particular vested interest group at the lower level dominates the higher level and ensures anti-development solutions, then the selection of inappropriate technologies results.

In all these situations, however, a development-oriented technology solution is facilitated by increasing the range of technological choice and by providing increased information.

Structure of Methodology

Several elements of the methodology of selection of appropriate technologies have been discussed in the preceding sections. In particular, consideration has been given to the constraints on the selection process, the set of economic, social and environmental criteria, the dialectical link between the selection and generation of technologies, the construction and comparison of technology profiles, the trade-offs between criteria and the iterative character of technology selection.

The inter-relationship between these elements can be displayed in a diagram (Figure 1) which also reveals the organization of the elements and the structure of the selection methodology. The diagram has been drawn for the case where the

decisions on constraints (such as product-mix, growth rate and centralization) are made outside the technology selection process. If, however, such divisions are within the scope of the selection process, the diagram must be amended so that the decision-making on constraints and the selection are within the same activity box.

Feed-back loops

Though the methodology diagram is self-explanatory and in fact summarizes in pictorial form the previous discussion, the feed-back loops in the methodology need some attention.

One feed-back loop links the bank of available technologies to the decision-making on the constraints to be imposed on the selection process. The basis for this link is that informed decisions on product-mix, growth rate and centralization can be made only with a full knowledge of available technologies. For instance, a decision on the product-mix for sweeteners (jaggery or crystallized white sugar) must involve an awareness of the range of technologies available for all the various sweetner products. In fact, this awarness may be far more important than an understanding of the different technologies for a particular sweetener product, e.g., crystallized white sugar. All this means that information on these technologies must flow from the bank of technologies to the decision-making apparatus - hence, the feed-back loop.

Another feed-back loop connects the selection process back to the decision-making on constraints. The aim here is that the constraints must reckon with the selection process, so that the constraints may be realistic and catalytic. For instance, a constraint of centralization may be externally imposed on the selection process in the belief that only centralized technologies meet objectives, but the selection process may reveal technologies which are adequately appropriate

despite the fact that they are small-scale decentralized technologies. Such information must obviously be fed back to the decision making on constraints.

Some other feed back loops leading to revised technology profiles through modified criteria and/or technologies and/or information on technology impacts have already been described and will therefore not be discussed again.

Problems with the Proposed Methodology

The methodology proposed here for the selection of appropriate technologies is substantially different from the methodologies currently in use. This very novelty may retard its acceptance. In addition, the delay may be extended for other reasons.

Firstly, even without intending to exaggerate the virtues of decentralized local technologies and the drawbacks of centralized technologies operating at higher levels, the thrust of the whole methodology is likely to strengthen the local level. Quite understandably and predictably, this thrust may be construed as a threat by groups with vested interests in the higher levels and in current systems of technology selection.

Among these groups are those engaged in centralized decision-making, management and resource control (including the control over capital), and also perhaps who are involved in the generation of technologies. Scientists and engineers tend to be universalistic and to search for generalized solutions. Local quirks of needs, conditions and materials are difficult to tackle from far-off laboratories and workshops because they demand intimate field experience. Central administration tends to look for nationally operated systems of resource allocation and control and nationally standardized solutions. The power of such an administration derives from glossing over local peculiarities, and its limits are exposed

when grappling with grass-roots problems. Professionals find that rewards, prestige and power increase in the same measure as the centralization of the decision-making. Finally, those who control and run profit-seeking enterprises tend to promote the expansion, integration (vertical and horizontal), and centralization of these enterprises.

There is considerable convergence and harmony of interests of all these groups, not only at the national, but also at the regional and global levels. This unity of interest may operate against the local level and, therefore, against the methodology of technology selection proposed here.

Secondly, it may be argued that the current mode of technology selection has a momentum of its own and the costs of moving to a new system are too great to warrant such a transition. There is - it is stated - an ongoing system of technologies which is increasingly large-scale and centralized, and "the monster has to be fed"; otherwise, there will be a serious loss of output.

Thirdly, the constraint of time is frequently invoked to perpetuate current methodologies of decision-making and technology selection. There is no time - it is argued - to search for appropriate technologies, and therefore it is best to adopt technologies used elsewhere. Sometimes, the time constraint is real, i.e., there is a genuine emergency such as flood, famine, drought or disaster. But, very often, the time constraint may only be imagined, i.e., the urgency is illusory; or it may even be contrived, i.e., decisions on technology are deliberately delayed to force a particular decision.

Fourthly, there is the question of imperfect information flow resulting in the selection process only looking at - or being allowed to look at! - a restricted set of contending technologies. By the time the other possible technologies enter the arena of selection, there is a fait accompli type of

situation in favour of current patterns of technologies.

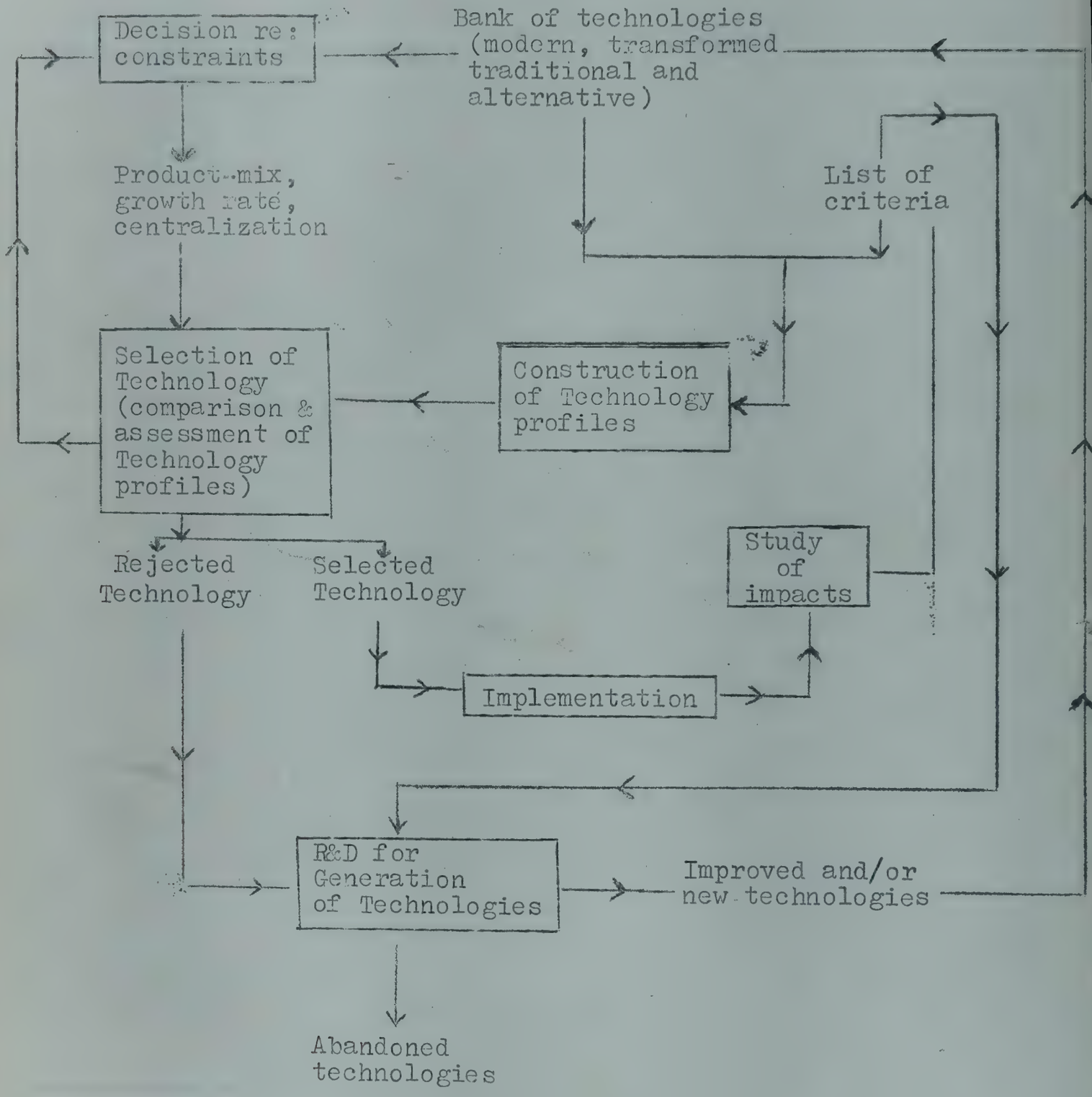
Finally, there is the fact that some technologies cater to restricted constituencies, in the sense tnat they benefit preferentially certain sections in society. If, therefore, the selection is in favour of technologies which overwhelmingly benefit currently underprivileged groups, the groups in power may not always take kindly to this new distribution of the cake.

Conclusion

Notwithstanding these various problems, the methodology of technology selection proposed here has one important factor in its favour - it is an integral part of the development process. The criteria of appropriateness have been specifically chosen for consistency with development objectives. Thus, the attempt to select appropriate technologies is a crucial aspect of the drive for development. Seen in this perspective, the obstacles facing the methodology of technology selection urged here are only a technological dimension of the obstacles which must be overcome to achieve development. And to the extent that this objective is a historical necessity, the new methodology of technology selection is inevitable.

No claim is made that this new methodology should be precisely of the form set out in this report. On the contrary, the methodology sketched out here is far from complete. It is embryonic in form, tentative in approach and exploratory in spirit, and is primarily meant as a scheme submitted for improvement, modification and refinement.

Figure 1 : Methodology of Selection of Appropriate Technologies



GENERATION OF RURAL TECHNOLOGY

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Lecture 1.2.3
Rural Technology Course

GENERATION OF RURAL TECHNOLOGY

Amulya Kumar N. Reddy

Introduction

The technology-society model for stratified society in strong interaction with the industrialized countries has revealed the following obstacles to the generation of rural technologies.

(1) The basic needs of the rural poor are not transmitted as demands upon the technology-generating institutions in developing countries.

(2) These institutions introduce into the innovation chain the same preferences, guidelines and paradigms as are used in the industrialized countries.

(3) The thrust of technological capability in developing countries is towards problems which are largely unrelated to the development goals of these countries.

The whole situation is aggravated by the fact that appropriate technologies have been invariably confused with low or primitive technologies. This is because, too often, the advanced character of a technology has unfortunately been adjudged with the trivial criterion of "scale of production", whereas in fact it should be determined by the extent of the scientific and engineering thinking that goes into the research and development. An additional source of confusion is connected with the question of simplicity. For use in the rural areas of developing countries, a product may have to be very simple, but this does not preclude the possibility of the innovation process (by which the product is arrived at) from being ingenious and subtle. To quote the adage: "any fool can make a solution complicated; it takes a genius to make it simple!"

It must be admitted here that many appropriate technology groups themselves have been responsible for initiating and perpetuating the belief that the technical capability required for the generation of appropriate rural technologies is of a lower order than that for western technology. It matters little whether this is due to inadequate understanding or to an attempt to bypass the established institutions of education, science and technology in the developing countries. The net result has been a widespread belief that appropriate rural technology is "second class" and not modern.

It is clear, however, from the discussion of the filter and guidelines appropriate for development that the only difference between western technology and appropriate rural technology is the difference in the wants transmitted by the filter and in the set of preferences or paradigms guiding the innovation chain. Otherwise, appropriate rural technology needs the same rigour and thoroughness and must be developed from as sound a base of fundamental science and basic engineering as is required for western technology. In fact, appropriate rural technology may need a much stronger foundation in fundamentals because, after rejecting the technological paths well-trodden by the developed countries, there is often no choice other than going back to firm first principles.

The importance of this viewpoint must be seen in the context of hopefully well-meaning, but in effect dangerous, advice that developing countries should not invest in basic research*. If such advice is acted upon, the result would be highly detrimental to the development of appropriate rural technologies.

Pre-requisites for the Generation of Appropriate Rural Technologies

The first prerequisite for overcoming the above problems is the establishment of clear-cut mechanisms to alter the

*Even though the share of basic research in the R & D budget of most countries is rarely more than 5-10%.

filtering process so that the relevant institutions respond to, and are biased towards, basic human needs, especially the needs of the neediest. These mechanisms must be directed towards the creation of an awareness of these needs and a commitment to satisfying them. However, a precondition for this alteration is a political framework which sanctions, or at least does not prohibit, such a new filtering mechanism. Given such a framework, much depends on the decision-makers who control R and D funds, and on the existence, within educational, scientific and technological institutions, of leaderships and core groups which generate an increasing response to the basic needs of the poor, rather than to the non-developmental demands of the elites.

The second prerequisite is that the scientists and engineers involved in the generation of appropriate rural technology should absorb and/or formulate the new preferences, guidelines and paradigms essential for the development of these technologies. Absorption is of course an easier process than formulation, but unfortunately the new preferences, guidelines and paradigms have not yet been elaborated and made explicit. This situation only increases the intellectual burden on (challenge to?) scientists and engineers, and compels them to understand the economic, social and environmental ramifications and implications of their areas of interest. This understanding requires in addition close contact with the prospective beneficiaries of appropriate rural technologies, i.e., the rural poor.

The third prerequisite is a new pattern of technological capability. Why a new pattern? Because the task of generating appropriate rural technology appears to be impeded by the type of technological capability that developing countries have and are currently growing and by the nature of linkages that their educational, scientific and technological institutions have and

are forging with domestic and foreign societies. Thus, most developing countries have followed a standard approach of establishing universities, institutes of science and/or technology, technical institutes and industrial laboratories modelled on the corresponding institutions in the developed worlds, with even their staff emulating counterparts in the industrialized world. As for the institutional linkages, the strongest links are with the demands of the elite, with counterpart institutions in the developed world, and with western technology. Furthermore, because of the inevitable financial stringencies, these institutions - like naturalized technologies - become, at best, cheaper and cruder versions of the corresponding western institutions, and at worst, complete parodies of the latter.

After a decade or two of their operation, it becomes apparent to national governments, which are under political pressure from the poor, that these institutions are making little contribution to the tasks of development. And thus arise the pleas and the exhortations to these institutions to devote themselves to the problems of the needy. But, such appeals hardly work.

The reasons for this predicament are discernible from the technology-society interaction scheme for developing countries. This predicament is an inevitable consequence as long as institutional linkages are virtually non-existent with the needs of the rural poor and with traditional technologies, and are very strong with elite demands, with institutions in the developed world and with western technology. The situation is worsened by the fact that most teachers, scientists and engineers are drawn from, and/or become part of, an elite which, in the dual societies of developing countries, is virtually cut off from its countryside and its rural poor. No wonder they are more familiar with London or Paris or Los Angeles than with villages even a few kilometres from their institutions.

An Alternative Strategy

But, there is an alternative strategy for developing countries to satisfy the prerequisite of a new type of technological capability necessary for the generation of appropriate rural technologies. This strategy consists of two parts:

(1) forging strong linkages between, on the one hand, the educational, scientific and technological institutions of these countries, and on the other hand, the needs of the rural poor and their traditional technologies; and

(2) drastically weakening the linkages of these institutions with elite demands and with institutions in the developed world.

In practice, this alternative strategy is most effectively implemented by each institution committing itself to a neighbouring rural area*, and to the generation of technologies appropriate to the development of that area. It follows from the understanding of development used in this conceptual analysis that a commitment to the development of a particular area must mean a commitment to the needs of the neediest, i.e., the rural poor, in that area. Further, since the generation of technological solutions accessible and acceptable to the neediest is very often likely to come through a transformation of traditional technologies, a study and evaluation of these technologies becomes an inevitable part of the commitment to a neighbouring rural area.

Methodology of Generation of Appropriate Rural Technology

Experience with this alternative strategy has indicated a detailed methodology for the generation of appropriate rural technologies (Figure 1).

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*The size of this area can be a matter of convenience, it may be a village, a cluster of villages, a district or a region.

Step 1: Identification of Felt Needs of Rural Poor: At the outset, it is necessary to make a distinction between felt needs and perceived needs. This is best done through a concrete example. Take the case of thatched-roof houses. Villagers are fully aware that thatched-roofs suffer from serious defects: they leak, catch fire, require frequent maintenance, harbour rodents, insects and reptiles, and are attacked by termites. Villagers, therefore, have a felt need for an alternative roof which is free of these defects. But, if they are asked what type of roof they want, they are almost certain to demand a mangalore-tiled roof or even a reinforced-concrete-construction (RCC) roof, i.e., they have a perceived need for mangalore-tiled or RCC roof. Thus, felt needs are those that specify the requirements, and perceived needs are those particular products or services which, according to the perception of the target group, fulfil its requirement.

It is obvious that the felt needs of a target group can be identified only through direct contact with the group and an intimate understanding of their living conditions. Neither can one sit in ivory-towered institutions and decide on what are the felt needs of people, nor can one base decisions on naive questionnaires which ask people what they want.

The identification of felt needs is best done either by social scientists or by technologists functioning as social scientists. In either case, the crucial qualities required are empathy and sufficient intelligence to define requirements from interviews with villagers. But, the primary direction of information flow in the process of identification of felt needs is from the people to the scientists and engineers.

Step 2 : Generation of Technological Options: Having identified a felt need, the next step is to formulate the various technological options for meeting the requirement. In this process, it must be realized that villagers are on the horns of a dilemma; they are confronted with a Hobson's choice of either

traditional technologies the inadequacies of which they are only too well aware of or the naturalized western technologies prevalent in cities and towns, which are far beyond the means of the poorest sections. The resolution of this dilemma requires the generation of a wider range of options. What is required is a heirarchy of technological options, starting from the traditional technology and ending with the western/urban technology, with each option higher in the heirarchy being more effective (or giving better performance) than the lower one - but at an increased cost. In other words, there should be a range of technological options of increasing cost-effectiveness. Ideally, the individual options in this heirarchy should be upward compatible, i.e., they should be capable of being transformed into the more cost-effective options with marginal increases of investment, and they should not preclude or pre-empt the subsequent choice of better options.

This generation of a heirarchy of technological options can only be achieved through a utilization of the heritage of modern science and engineering. The target group cannot achieve this increase of options on its own, because its awareness of modern principles, materials, techniques, processes, equipment, etc. is limited by its circumstances and areas of specialization. Hence, the major role in this process must be played by scientists and engineers, but hopefully the target group will not be excluded from those aspects of the innovation process where they can contribute. Nevertheless, the main flow of information in this process is from scientists/engineers to the people.

Stept 3 : Demonstration of Technological Options: The next stage consists of exposing the target group to those new items in the heirarchy of options that the target group is unlikely to have come across. This corresponds to the test marketing phase in which consumer reactions and suggestions are actively

solicited. Invariably, the comments of the target group to the various options are extremely valuable, but the soliciting of comments implies a totally different attitude from the conventional : "they are ignorant, and we know what's good for them". It is interesting that if the target group is poor, all the standard tenets of marketing are ignored, i.e., tenets such as "the customer is always right!", "involve the client!", "test-market a product before launching it!", etc.

It is necessary to proceed with the understanding that the poorer a rural household is, the less capital and/or resources it has to invest on new technologies, and therefore the more cautious it must be with regard to unproven innovations because its survival depends upon a correct assessment of the new technology. There is a real conflict between the opposite attitudes towards a technological innovation - the planner, scientist, engineer, and technology disseminator are all obsessed with the benefits of success and the glory derivable from this success; in contrast, the rural household is preoccupied with the consequences of failure and the utter ruin that such a failure will bring in its wake. And far too often, the extreme caution of the villager has been completely justified - the countryside is littered with many a technology which has been rejected because it was rushed in half-baked and, like the girl in the nursery rhyme, "when it was good, it was very very good, but when it was bad, it was horrid". The solution lies in approaching the problem with the view that (1) villagers are rational because they have learnt through long experience that their survival depends on careful risk analysis and on meticulous assessment of costs and benefits, and (2) the selection of technological options improves by securing the participation of the target group.

Step 4 : Selection of Technological Options: The culmination of the whole process of exposing options to the target group and of eliciting its reactions is the identification of one or more specific technological options as suitable for diffusion. Simultaneously, there is a fusion of felt needs and perceived needs, but at this stage, the perceptions of the target group will be based on a real choice involving a sufficiently large number of options.

Step 5 : Development of Hardware+Software Technological Packages: Once there is clarity with regard to the particular technological option(s) which need(s) to be developed, their development must be taken up in full earnest. But, there are two aspects of a technology:

(1) hardware which is the embodied form of the technology - machines, equipment, processes, etc., and

(2) software which is the disembodied form of the technology and represents the way(s) of using the hardware.

Neither of these aspects is any less important than the other. Despite this, educational, scientific and technological institutions tend to concern themselves almost solely with the hardware aspects of technology, though the software aspects, viz., raw materials procurement, credit, organization, training, management, marketing, etc., are of as great importance. Little attention is paid by these institutions to the design of complete hardware and software packages. But, it is only when such total packages are worked out that the technology stands a chance of being successfully diffused and disseminated.

Implementation of Methodology of Generating Rural Technologies

The methodology of generating rural technologies outlined above needs simultaneous implementation at a hierarchy of national, sub-national and institutional levels.

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Implementation of Methodology of Generating Rural Technologies

The methodology of generating rural technologies outlined above needs simultaneous implementation at a hierarchy of national, sub-national and institutional levels.

The national or macro approach should be directed towards the preparation, on-going modification and refining, and implementation of technology plans oriented towards development, of which plans for appropriate rural technologies must be an integral part. It is in accordance with these plans that the national R & D budget must be framed and apportioned. This technology planning should be linked with the process of selecting and choosing technology appropriate to urban and rural development, so that better technological options than those available can be identified, and research and development work towards the development of these technologies can be initiated. Of course, insights into these alternative technological options for rural development can only emerge from greater sensitivity to the problems of the rural poor and more intimate contact with their problems. Such sensitivity to needs and intimacy with problems cannot be attained by planning form the cloistered chambers of the national capitals of developing countries. Hence, what is necessary is inputs from the grass-roots level, and herein lies the importance of work at the institutional or micro-level.

Virtually all the educational scientific and technological institutions of developing countries have, at least in an embryonic and rudimentary form, the multi-disciplinary competence to tackle the task of developing appropriate rural technologies for meeting the basic needs of the needy, particularly in rural areas. These functioning institutions must, therefore, constitute the main basis for the generation of appropriate rural technology through a deliberate and formal commitment to the problems of development, and particularly to rural development. Such a re-deployment of efforts with existing infrastructures is a far more effective measure than the creation of new institutions for appropriate rural technology.

A basic assumption underlying this new strategy is that institutional generation of appropriate rural technology will continue to play a major, but hopefully not exclusive, role in innovation for rural development. It is envisaged that the actual users and operators of appropriate rural technology, i.e. the rural people themselves, will have a crucial role in innovation particularly in the continuous testing, refinement and adaptation of new technologies. Indeed, it is hoped that a constant interplay between institutional and popular innovators will enhance the appropriateness of rural technologies. What is rejected in the new strategy is the argument that the institutions of education, science and technology in most developing countries are so moribund and irredeemable that only non-institutional voluntary groups can generate the new technology. Such groups may have a part in technology generation, but it can only be marginal, in view of the inevitable limits to their multi-disciplinary expertise and their facilities for research and development. This judgement rests, however, on the assumption that appropriate rural technology is not second-class technology and that its generation is not a trivial exercise.

The activities of institutions at the micro-level can be linked together interactively at the sub-regional or meso-level, i.e., at the level of districts or states (groups of districts) corresponding to the next higher level of local government. Here too the basic approach should be a commitment to the problems of a particular area of the country and to the problems of the poorest sections of the people in that area.

This alternative strategy of generating technological capability and developing appropriate rural technologies through a commitment to a particular rural area, i.e., to the problems of the poor in that area, is likely to ensure satisfaction of the third prerequisite for the generation of appropriate rural technologies, viz., the growth of a new type of technological

capability. In addition, this same strategy is also likely to satisfy the first two prerequisites. Thus the establishment of close links between educational, scientific and technological institutions on the one hand, and villages and rural poor on the other, is the surest way of creating awareness of the basic needs of the neediest. If this awareness is transformed into a commitment to rural development, then the institutional and personal filters will start responding to those social wants which correspond to the basic needs of the poorest, without which response the generated rural technologies will not be compatible with rural development objectives. Similarly, it is only close contact with rural areas and those below the poverty line which will faciliate the formulation of preferences and guidelines and paradigms consistent with true development.

Distinction between the Generation and Diffusion of Appropriate Rural Technologies

Technology generation for its own sake is a sterile exercise; for it to have meaning and purpose, it must lead to the diffusion of technology. In fact, the generation and diffusion processes should be linked, so that each reinforces and influences the other.

But, the need for this relationship must not be allowed to blur the crucial differences between the two processes. Unfortunately, this blurring takes place too often, and it is therefore necessary to make the differences explicit.

Firstly, the actors in the two processes are usually quite different - whereas R and D institutions (at the macro-, meso-, and micro-levels) are mainly responsible for technology generation, the process of technology diffusion is usually the responsibility of a development agency, acting in coordination with the people, local self-government organs, R & D institutions, financial and credit institutions, and marketing organizations. Thus, technology generation can be achieved by the

solo effort of R & D institutions which can restrict themselves to hardware and/or software development, but technology diffusion must be a multi-institutional effort involving the implementation of complete hardware + software packages.

Secondly, the funding agencies for the two processes are invariably quite different — technology generation is funded by R & D grants from government ministries, scientific agencies, and public and private sector industries, but technology diffusion is funded by development agencies.

Thirdly, the power structure need not necessarily be disturbed by the generation of technology, but it cannot but be affected by technology diffusion.

Fourthly, the levels of operation of the two processes are quite different — technology generation can be achieved at the institutional level; technology diffusion must be accomplished at the level of society (even a village is a mini-society).

Fifthly, and as a consequence of the above two differences, the technology generation process is much more autonomous than the technology diffusion process, in that, given (a) funds for R & D, (b) sufficient awareness and commitment among those doing R & D, and (c) the absence of direct political hostility towards the R & D, the generation of technology appropriate for rural development can be accomplished successfully. In contrast, technology diffusion cannot be achieved against the wishes of the ruling groups in society. And, where the technologies to be diffused are against the vested interests of the privileged — which, in dual societies, they often are, if they are indeed technologies appropriate to development -- then the success of the diffusion depends on the particular balance of power between various groups in society. The ruling group is rarely homogeneous, and if, within this group, some powerful sections, e.g., the urban elites, are not inimical to the diffusion of appropriate technology in rural areas, then the process stands a favourable

chance. If, on the other hand, all the privileged sections are unitedly opposed to the technology, then the attempt to diffuse it is almost certain to fail, nevertheless the attempt must be made as an essential and integral component of the struggle of the under-privileged and its allies for a more just and equitable society. Thus, a necessary condition for the successful diffusion of technologies appropriate for development is a large measure of active political support.

Sixthly, the role of the people in the two processes is quite different. Though close consultation with the people is vital for obtaining better insights into local needs, traditional solutions, local conditions, local materials and local skills, and though these insights are quite essential for ensuring the appropriateness of technology, an R & D institution can, in principle, generate technology without the active participation of the people in the designs, calculations, experiments, fabrications, etc. In other words, appropriate (including socially acceptable) technology is unlikely to be generated by R & D institutions without close consultations with the people, but their active participation in the technology generation per se is not necessary. This is not to deny that widespread popular participation in technological innovation should be the objective, and that an intimate interplay between institutional and popular innovators is an ideal state of affairs. In contrast, the active participation and involvement of the people is a necessary condition for technology diffusion.

These distinctions between technology generation and diffusion, particularly between social consultation and single-institutional work for technology generation vs social participation and multi-institutional work for technology diffusion, lead to some important perspectives and conclusions.

For instance, it is clear that institutions of education, science and technology can assume — and successfully discharge — the responsibility of generating appropriate technologies. If, however, these institutions also assume the responsibility for diffusion of technology, they must realize that:

(a) they will have to lead, coordinate and manage the concerted action of a large number of institutions, viz., development agencies, local self-government organs, financial and credit institutions, marketing outlets, etc., and

(b) they are almost sure to deviate from their charters of education, science and technology.

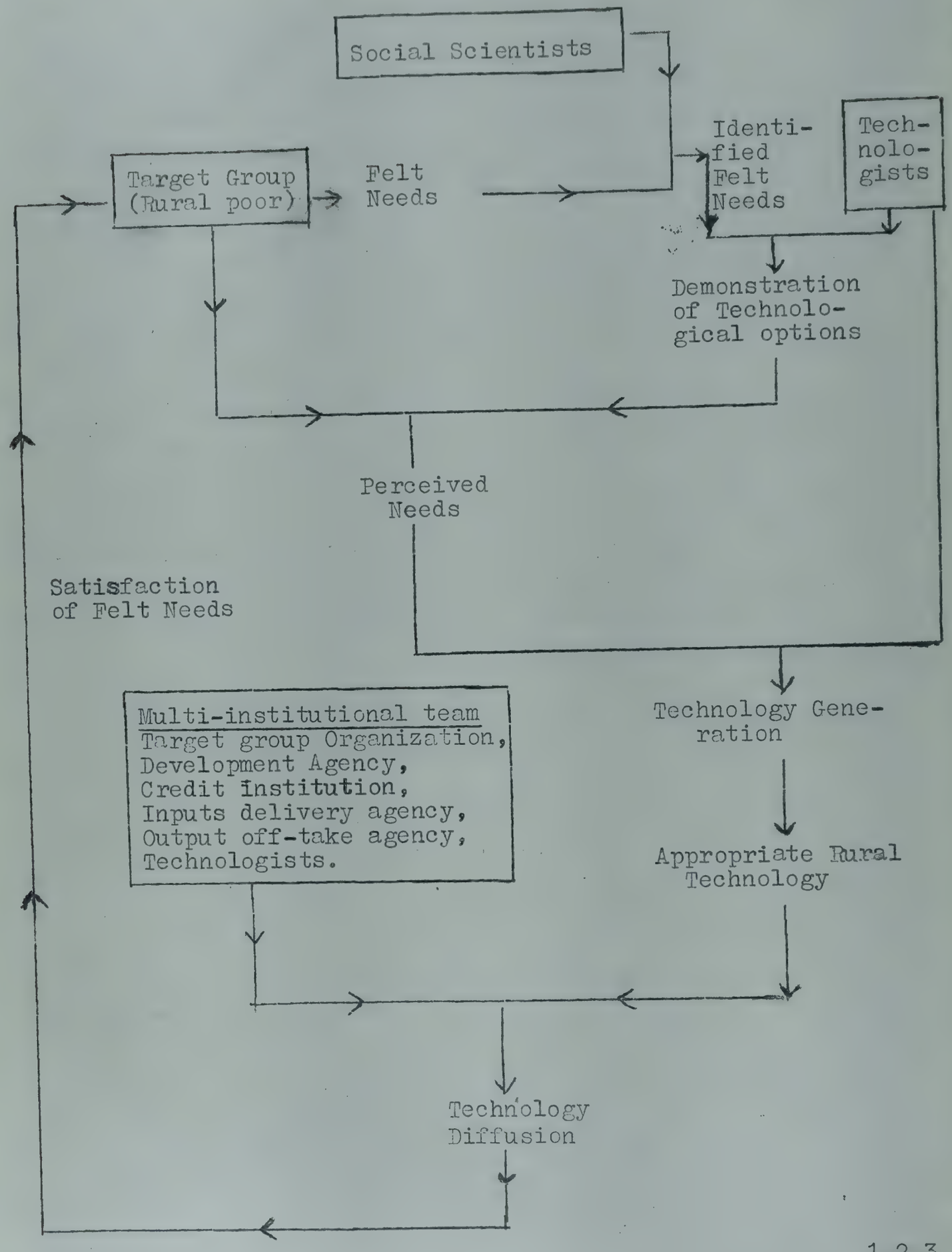
Whether they are structured and competent to discharge this onerous responsibility is a moot question. In general, it would be unwise for educational, scientific and technological institutions to assume this responsibility for technology diffusion without being aware of all the implications and consequences. On the other hand, R & D institutions must be an essential part of the technology diffusion process — the vital need for their active participation in the process follows logically from the linkage between the technology generation and diffusion processes.

In conclusion, therefore, micro-level institutions of education, science and technology can, and should, assume leadership in technology generation, but not in technology diffusion — they should only be members of the multi-institutional teams to diffuse technology.

This conclusion need not be valid in the case of macro- and meso-level institutions of science and technology, for example, national and provincial councils or departments for

science and technology. Such councils and departments, by their very nature and responsibilities are already removed from the laboratories, offices, drawing-boards and workshops where actual R & D work takes place, and are, in fact, only promoting, catalysing and co-ordinating R & D work. Hence, macro- and meso-level institutions -- can lead the process of technology diffusion. But, for such leadership to be effective, it should be formally accepted by all the concerned institutions - development agencies, local self-government bodies, financial institutions, etc. Even in the absence of such a formal acceptance of the leadership of a macro- or meso-level institution of science and technology, the latter two types of institutions can still play a powerful catalytic role in the diffusion of technology. Between them, if speed and effectiveness are inversely related to the size and complexity of an organization, it may turn out that macro-level institutions are too ponderous and ineffective to play the catalytic role efficiently. Hence, the hope for successful technology diffusion lies in the hands of meso-level provincial councils for science and technology.

Figure 1: Methodology for Generation of Appropriate Technologies



GENERATION OF RURAL TECHNOLOGY (PART II)

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Lecture 1.2.4
Rural Technology Course.

GENERATION OF RURAL TECHNOLOGY (PART II)

S.P. GOVINDA RAJU

INTRODUCTION

There is much current interest in designing devices for broadly aiding the development of rural areas. Design for rural use is a subject intimately connected with the social impact of design and the following is an attempt to clarify this connection and to provide some guidelines for potential designers.

WHAT IS DESIGN

One may define design as a goal oriented activity leading to a design or product which promises some desired result by interaction with the environment which is given. Other results, not necessarily desirable and often unforeseen follow automatically even though great pains are often taken to reduce the undesirable effects to a minimum. An illustration is given below.

A motor car in the environment of a city produces the desired result of moving people from one place to another with spead and comfort. While it does so, it necessarily burns some petrol. It also produces noise and pollutes the air. It also cause traffic jams and accidents. It creates a need for parking space and imported oil.

It can be noted that the car cannot produce the desired result in a very different environment - say without roads and/or oil and/or rich people to pay for it.

Thus it is clear that the ability of a design to produce results is affected by the environment and thus one always considers design in the context of a real or assumed environment. The environment in the sense it is used here includes a large complex of factors which affects the ability of a design in producing the result(s). It is also to be noted that a new design affects the environment in new ways and thus may alter it over time. Thus the design environment is a dynamic entity constantly changing partly due to the combined effect of all design activity that goes on. The environment thus changed calls for new design and this development of the envrionment goes on and on.

THE DESIGN ENVIRONMENT

The environment for any design can, in general, be grouped into three types: physical, socio-economic and technological.

We apply the term physical factors to all physical aspects of the environment which exist independent of the designer's immediate activity and are generally not very controllable. In the context of rural areas we may consider sunshine, wind, rainfall, soil types etc. as the physical factors. There may be considered as basic resources available to the designer.

In socio-economic factors we include the structure and organisation of the population, available manpower and money, the attitudes of the people towards various aspects of life (i.e. culture) etc. These factors are important in deciding issues like design for individual as against group use, the trade-off between various conflicting requirements like for example economy against safety etc.

The term technological factors will be used for denoting the method of production including tools and techniques which can be used in production and maintenance of

designs. It is approprite to note here that technologies can be energy intensive and large scale (as in a typical modern furniture factory) or labour intensive and small scale (as in carpentry using hand tools) while still meeting the essential requirement of producing a comparable end result (furniture).

As noted earlier, a designer assumes an environment and then chooses a design which is in some sense the best for that environment. Clearly the best design for one environment will be different from the best design for another if the two are significantly different from each other. This implies that designs evolved in the 'developed' countries must be unsuitable for production and use in the 'developing' countries in small or large ways depending on the specific design in question. As a result, when designs are imported from Western Countries (and it is usual practice to do so) and introduced without change into India, we often end up with unexpected problems of various types - some technical and some socio-economic ones. Thus it is worthwhile looking at the differences between the environments characteristics of Western countries and India - its villages in particular.

THE RURAL ENVIRONMENT

We may briefly state some important characteristic of the environment in Western countries for highlighting its contrast with that of rural India.

Western society is highly organised. The means of production (Technology) is highly concentrated and energy intensive. Goods for mass consumption are produced and delivered through a market mechanism which favours quantity production of expensive articles which are easily transported over vast distances. The designs are generally beyond user maintenance. These devices demand the imput of abundent high quality energy (most often well regulated electric, oil or

gas supply) and are often energy inefficient. As a consequence of the above, the needs of the poorer sections of s society are given little attention.

As against the above, rural India presents a vastly different picture. The villages are weakly organised and all economic activity is of comparitively small scale. Some of the products required by it are produced in cities and brought in. These products are generally simple (like cooking vessels, plastic buckets, clothing etc.) and need little maintenance. Energy of any quality is scarse and muscle power is an important source of high quality energy and is much used in agriculture. There is little design activity in the villages and the environment till recently was largely static at a very low level of prosperity.

DESIGN PHILOSOPHIES FOR RURAL AREAS

The large difference between the environment in rural areas of India and Western countries implies that new products designed to aid the development of rural India must somehow reflect this difference. To provide guidelines for potential designers (i.e. a designe philosophy) in evolving new designs aimedmat rural development one may consider models for the development process. Each model can start with a set of guidelines and one can study the consequences of following these. Naturally such a study is complex and is seldom quantitative. In this context people often consider 'scenarios' of development and based on these try to advocate a particular design philosophy which presumably promises a certain, speedy and durable development process starting from the rural environment as it is now.

A possible design philosophy can be derived from the so-called western model for development which derives from a study of western countries during their period of

development. But the deficiencies of such a philosophy are now obvious. The west developed in an environment of cheap energy, abundent raw materials and low population density. This combination does not exist in India and its villages and so this route to development is now unworkable.

Faced with the situation above, people have tried to build other models of the development process. Some small scale attempts in rural development to establish the feasibility of development without large inputs of commercial forms of energy have also been tried. Based on these people advocate what is loosely termed the 'Appropriate Technology (AT) route to rural development. The term AT is not sharply defined and often means different things to different people. But, broadly it implies reliance on local resources. Designs employing the AT concept are expected to be simple to produce (i.e. without large investment) and not use electricity from a power grid or oil brought from far away. Bio-gas plants, Windmills, Hand pumps, Wood stoves etc. have become symbols of the AT concept. Though bicycles do not satisfy some of the principles stated above, they are generally considered acceptable.

APPROPRIATE TECHNOLOGY AND ITS IMPLICATIONS

The quidelines for a designer following from the concept of AT can be roughly characterised as follows:

(1) low capital

(2) use of local materials whenever possible.

(3) employment of local skills, labour

(4) small scale organisation - if possible on mutual aid basis.

(5) ease of understanding and maintenance by user

(6) use of decentralised and renewable energy sources - say.wind, sunlight, biogas, animal power, water power etc.

(7) adoptable to moderately different circumstances with little effort (This is the 'soft design' approach)

It is appropriate here to consider the implications of designing in conformity with AT principles. Design, as stated earlier, is the art of making things intended to produce some desired result with minimal side effects for a given environment. Often there is a choice of designs which will, while differing in many ways, still produce the main result sought. Any philosophy reduces this choice and it is not abvious that design solutions will always exist subject to the constraint of a philosophy. Even when they do, it is not obvious that people will adopt them specially when alternatives are available. Thus, even though one can made a good case for adopting AT principles, sucess of designs built to these principles is not assured. Thus, as of now, AT provides a new direction for the designer to shoot at and appears to promise some devices with potential for aiding the development of villages. It is still to be seen how much AT will actually deliver. This implies that one should not be very strict in confining designs to AT principles.

DESIGN EXAMPLES

Over the last several years new designs for rural use have been attempted in a number of areas like water pumping, housing, bio-gas plants etc. Some of these are described in details in other sections of this course. As a typical example, the design of a Windmill based on a sail-type Savonius rotor is included in the next lecture.

DIFFUSION OF TECHNOLOGY FOR RURAL DEVELOPMENT

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Lecture 1.2.5
Rural Technology Course

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FOR DISCUSSION

DIFFUSION OF TECHNOLOGY FOR RURAL DEVELOPMENT.

Vinod Vyasulu*

In an earlier lecture, Professor Reddy discussed the issues related to the generation of technology appropriate to rural development. He ended his lecture by referring to the fact that mere generation of technology would be a sterile exercise. For the process of rural development, it is essential that such technology be diffused or disemenated from the R&D institutions to the ultimate users - the farmers, handicraft workers and small industrialists. And this diffusion is in some ways quite different from generation of technology.

If we go through the points of difference he lists, we find that one critical element in it is the fact that it is a societal level activity involving a host of different kinds of institutions in a multi-institutional effort.

Historically, there have been different ways in which technology has been diffused. It is possible

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* Assistant Professor, Indian Institute of Management Bangalore. I have benefitted a great deal from discussions with Prof.AKN Reddy, ASTRA, IISc. and Mr.T.S.Kannan, Chairman, NSIC. I remain solely responsible for all errors, Comments are invited so that a revision may be made at a later time.

distinguish four different types:

1. Diffusion through the market. This has been the normal pattern of Western society. Whenever a businessman saw an opportunity for profit, he would accept and implement a new technology. And, once in business, he would accept any innovation that would reduce his cost of production. As unions grew stronger and wages rose, this led to a search for labour saving technologies in the Western countries. Many of the "biases" of Western technology are, in fact, the "bias" of the "free" market operating in these countries.

It has, however, been seen that this process, if adopted by the underdeveloped countries, often only reinforces that under-development.

2. In contrast to the market system, is the centralized, top-down planning system. Such a system, for example, operates in the U.S.S.R. But it also operates in some measure in countries like India that have opted for a mixed economy in which the state has a major role. While there are many differences between the soviet and Indian models in this regard, it nevertheless remains true that decisions on technological diffusion are taken in New Delhi and often do not have the desired effect. It is in this context that

large questions like the recent BHEL - Siemens and the Fertiliser consultant controversy need to be seen.

So far as rural development is concerned, this top down process is not suitable, since the essential links to the local level are missing. When the persons directly concerned with problems of rural development do not feel that they have been listened to by policy makers, then they are unlikely to push hard on directions from the top.

3. A Third type of diffusion is that associated with the intermediate or appropriate technology movement in the West. In reaching to the problems caused by large scale production, this movement sees solutions at the level of the individual. He must make his own tools; grow his own (organic) food, generate energy for his house with his own solar panel and so on. This extreme in individualism is only possible in the context of a small group in a rich society. It is too expensive for rural development and it does not promote the feeling of participation and solidarity that rural development requires.

4. The fourth type is one that combines general guidless at the macro-level with a decentralized process of decision making and implementation at other levels. Recognizing the importance of participation and involvement at the local level, such a process

builds upon regional institutions (for example macro-level state councils) which gear their R&D effort to the areas in which they are located. Assessments of resource potential, national priorities and so on are made at the national level through a process of mutual discussion, but implementation may take many forms, depending on regional needs.

Such a process has worked excellently in the agricultural sector, where the green revolution is a testimony to the success of the process of technological diffusion. The "lab to land" programme has many lessons to offer to all who are interested in this issue.

This is the pattern of diffusion of technology that seems to hold the maximum promise for rural development. Some experiences at the field level may be useful to understand the various dimensions of this complex process.

Hosiery in Tirupur

A large number of very small manufacturers of cotton hosiery - mainly banians and underwear - in Tirupur approached the NSIC for help in "marketing" their products. They felt that the competition in the market was such that they could not otherwise survive.

After studying the product and the market, the NSIC found that the Tirupur hosiery would be unable to hold its own unless (a) some quality control in the form of ISI standards were adhered to, and (b) the consumer was made aware of the fact that a minimum quality was being maintained.

Since it was the small producers who came for help, they were prevailed upon the form a "consortium". This consortium was then given the necessary support to set up quality control tests. The consortium was also helped in marketing through the use of a brand name (NIC) which the NSIC helped to advertise. Within one year, the manufacturers came back to NSIC with a request to help them find a better quality of elastic since this seemed to be the major factor inhibting their growth.

Today, the Tirupur producers are in the export market.

Handmade Paper

Some small units that were set up with the support of the KVIC approached NSIC for help in "marketing". Once again, a consortium was formed (first in Tamil Nadu, and now planning to expand into an All India one). An examination of the industry showed that

1) one of the units had developed a new machine called the cylindrical mold vat, which reduced

dondery and improved productivity without using power;

2) the KVIC did not feel that the new machine should be popularized,

3) the manufacturers must confine their production to certain categories of paper, such as file boards, and

4) it is necessary to get into R & D to see alternate sources of raw materials for this industry.

So far as marketing was concerned, for items like file boards, orders were secured through DGS&D and passed on to the consortium. This helped them a great deal to recover from sickness. However, jurisdictional issues have slowed down progress in diffusing the new machine.

Tapioca Starch

Tapioca is eaten in Kerala, which is its largest producer. In Tamil Nadu, however, there is a good deal of Tapioca that is not eaten. In Dharmapuri, a backward district, there are a number of very small (and very poor producers who make Tapioca starch). Tests have shown that this starch is well suited for certain operations in textile mills.

The starch being a seasonal product, these small producers were the victims of middle men who exploited the fluctuation in prices - which ranged from Rs.140/- per bag to Rs.230/- per bag. The producers got negligible returns on their investment and production.

In this case, the NSIC set up a depot in Salem and assumed the producers a uniform price. Within one season, the price they received shot up from a high of Rs.140/- per bag to an average of Rs.195/- . This required only a buffer stock operation on the part of NSIC, in co-operation with a starch producer consortium. Once a stable price was assured, efforts were made to extend the market. This process involved SITRA, Combatore. The mills had to be convinced that Tapioca starch was not inferior to the maize starch they were using. This is a slow process, but, over the last two years, orders for this starch have begun to come in from places as distant as Kanpur. And given this credibility, the NSIC is putting pressure of the consortium to undertake R & D to reduce the health hazards of those who work in producing starch. But this aspect has not yet shown results.

Rice Husk Ash Cement

This is a different type of situation altogether. The NSIC found that there were several organizations that claimed to have the technology. But when requested to provide the blueprints for a pilot plant, only IIT Kanpur responded. Even here, the rights for the use of the technology in South India had been given to a party in Shimoga who was not producing this cement, but would not also permit others to enter the field.

The NSIC pilot plant therefore had to be located in North India. Along with some young entrepreneurs, a unit has been set up in Kurukshetra and it has just gone into production. An assessment now needs to be conducted.

Two other projects - the artificial limb developed at SMS Hospital, Jaipur, and the urban toilet system called Aulabh Souchalaya at Patna, offer interesting insights into the process of technological diffusion.

In looking back on our experiences, we find the validity of the differences between generation and diffusion that have already been highlighted by Professor Reddy.

We find also that the field situation is one in which, although science and technology may be key elements, the process begins with such problems as "marketing" or "finance", and that the results of R & D often come in as elements in a "solution" to these. It is in technological diffusion that the need for team work and different levels is absolutely critical.

ENVIRONMENTAL IMPACT ON SOCIETY

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Lecture 2.3
Rural Technology Cour

INTRODUCTION

I have been asked to address myself to the problems of environment. It is evidently a vast and complex problem. In order therefore to organize this material, I have decided to focus here on the implications of environmental degradation with respect to the ability of our society to meet the basic needs of its members. For all of us would agree that the most serious issue that confronts our society today is the fact that we have been unable to fulfil the basic minimal requirements of the vast bulk of our population in spite of three decades of planned development. I would like to put before you the thesis that a major factor contributing to this failure has been our neglect of the degradation of our environment. If this is so, as I hope to demonstrate, then our environmental concerns are not mere impediments to development; rather, our lack of concern for the degradation of environment has been a major cause of the evident failure of the development strategy so far pursued by us.

BASIC NEEDS

We can define five basic needs of the population in a predominently agricultural country like ours. These are food, fuel with which to cook this food, shelter, fodder for the domestic livestock and maintenance of the fertility of the soil. It is now abundantly documented that a large and increasing proportion of our population is malnourished, that fuel for

cooking is increasingly scarce for the people, that the bulk of them do not have adequate shelter, that our large cattle population is also half-starved, and that we are losing fertile soils over vast tracts. Much macro-statistics is available on all these problems which I will not enter into. Instead I will present here specific case studies to show how environmental degradation in different parts of India is affecting the ability of our population to meet these basic requirements.

FOOD

The one component of nutrition in shortest supply for our population is protein. Our coastal population, however, had access to cheap and relatively abundant protein in the form of fish. These fish stocks had been exploited for centuries by the fishing communities using traditional craft and gear which limited them to exploitation of inshore stocks roughly within the limit of five kilometers from the sea shore. Our offshore fish stocks had remained largely unexploited. Beginning with the early 1950's we began to introduce mechanized trawlers and purse seiners to tap these offshore resources. However, no careful planning went into ensuring that this increased intensity of fishing will not damage the fish stocks themselves. For, like all living resources, fisheries are potentially indefinitely renewable resource provided our harvest is limited to the interest on the capital. If we intensify the harvest

beyond this level, and start eating into the capital, the capability of the resource to renew itself is impaired and the resource will be destroyed. This has been the experience of other intensive fisheries such as that of the North Sea as early as 1930's.

As a consequence the nations fishing the North Sea have restricted the number of fishing crafts and the minimum mesh size of the fishing nets. No such restrictions were imposed when mechanized fishery was introduced to India. While the minimal mesh size allowed for the trawler net in the North Sea is 800 mm., we are fishing with nets of 32 mm. mesh. Furthermore the size of the trawlers chosen is too small for them to fish effectively in the offshore waters. As a result all the trawlers have concentrated their fishing in the same inshore zone exploited by the traditional fishermen. The trawlers further disturb the seabed and damage the spawning grounds of fish.

All of this unregulated intensification of fishing has led to over-exploitation of stocks. In Goa a doubling of the fishing fleet has led to no increase in total fish landings in the last few years. Off Cochin which is more seriously overfished, the total prawn catches have in fact declined to 1/3rd of the earlier level. In any events the total yields from inshore waters have increased very little beyond those obtained by traditional fishermen without consuming all the diesel and nylon that modern fishing craft do. At the same

time, a very large proportion of the fish caught by the mechanized boats is being canned and exported, so that fish prices have soared and the once cheap and abundant source of protein for the coastal population is no more so abundant and far more expensive. The net result of fishery development has therefore been an over-exploitation of our inshore fish stocks and a loss of a valuable protein source to our coastal population.

Apart from over-exploitation our fish stocks have also suffered seriously through marine pollution by a series of chemical industries letting out their effluent without proper treatment.

FUEL

The single, most important energy requirement for our population is that of fuel for cooking. For the vast majority of the population this is met by fuelwood collected from scrubland or forest and from dung. The latter use is highly undesirable, for it involves a loss of valuable fertilizer for the fields. There has been no substitution of these traditionally free fuels by commercial energy such as electricity or kerosene anywhere in our rural areas. In fact the National Sample Survey data show that the ability of the rural population to consume commercial sources of energy has declined from 1950's to 1970's.

Our energy and forest policy has nevertheless completely ignored this major energy need of our society and concentrated on the generation of commercial energy for the urban-industrial sector at the cost of the fuel needs of the rural population. As a case study, I would like to present the experience of Mulshi hydroelectric project, one of the earliest in India. This project was taken up by the Tatas in 1920's. It is based on the damming of an east-flowing river in a narrow river-valley in the high rainfall zone near the crest of the Western Ghats of Maharashtra. The river-valley is occupied by peasants who used to cultivate paddy on the flat lands, and millets on the lower hill slopes. While cultivating the hill slopes in a shifting cultivation system, the peasants used to leave intact a considerable tree growth of economically valuable species such as mango.

The project has submerged the rich paddy fields of the peasants with very inadequate compensation for the loss of this land. When the project was initiated the peasants launched a very powerful agitation against the usurpation of their land without proper compensation. One of the songs of this agitation has very telling lines: 'You are extinguishing the wick lamps in poor farmers' homes to light up the latrines of Bombay.' In the end, the agitation was unsuccessful and the peasants lost all their paddy lands. Thus impoverished they simply shifted up the hill slopes and intensified the shifting cultivation.

Unable to sustain themselves on the shifting cultivation alone, they sold off the tree growth on the slopes for the manufacture of wood charcoal for consumption in Bombay. Leading to soil erosion, this further reduced the productivity of their lands, and they have encroached on the Reserved Forests of the upper reaches of the hill.

Today, the landscape stands totally desolate with the subsistence base of the local peasants completely destroyed. Soil eroding from the bare slopes is rapidly silting up the reservoir. At the same time the fuelwood resources of the region have been completely destroyed. And there has been no serious attempt so far, either to stave off this destruction of fuelwood resources or to replenish them.

SHELTER

The bulk of our rural population has always taken care of its own housing requirements. All along the Western Ghats tracts at least this has been based on bamboo - a most versatile plant. Split bamboo strips and mats form the basis of walls of the huts, bigger bamboos serve as pillars and beams for the roof. And bamboo mats form doors and windows. When bamboo is abundantly available, a bamboo hut can be built quickly, and with very little effort by the people themselves.

And bamboo was abundant on the Western Ghats till it

became the raw material for paper industry. The first paper mill of Karnataka was established in 1930's at Bhadravathi on the assumption that it will perpetually meet its resource requirements from the Bhadravathi Forest Division. The mill was prescribed certain silvi-cultural procedures to be followed in harvesting bamboo. Our recent studies have revealed that these silvicultural procedures were inadequate to maintain bamboo stocks. Moreover, following them implies an increased harvesting cost and the contractors supplying bamboo to the paper mills by and large ignore these prescriptions. The current estimates for Karnataka are that the annual increment to bamboo stock is 1.35 lakh tonnes, while the annual harvest is 1.6 lakh tonnes. Something like 80 per cent of this harvest is for the paper mills. As a result bamboo has been wiped out over large areas.

Bamboo, which was earlier available essentially as a free commodity to the rural population, enabling them to construct houses essentially free of cost, now costs them Rs.1200 per tonne. At the same time, the paper industry which is primarily responsible for the destruction of the bamboo stocks, continues to pay a nominal price of Rs.15 per tonne.

The Government is now thinking of Janata houses, each built at a cost of Rs.10,000 to provide rural housing. It is quite clear that we do not have the financial resources to provide the required number of houses at such a price. So

we have first destroyed through improper exploitation a resource which made possible essentially free housing to our rural population, and are now helpless to provide them with any alternative.

FODDER

India is a land of cattle which serve several very important functions for our farmers. They are the only source of traction power available to most of them, a source of fuel and fertilizer and of milk. The cattle depend on straw from the field crops and on browse from the trees for their fodder requirements in the dry season. Both these sources have suffered a drastic reduction in recent years. The introduction of high yielding dwarf varieties has meant a considerable reduction in straw production. The replacement of natural tree growth by plantations of pine, eucalyptus and teak has meant a loss of palatable browse.

The problem is particularly acute in the Uttarakhand region of the Himalayas. Here the cultivation of the terraced hill slopes heavily depends on the use of natural tree leaves from the oak forests mixed with dung of animals feeding on such browse as fertilizer.

With the opening up of the Uttarakhand region by roads these natural forests have been rapidly over-exploited, and

replaced by plantations of trees of no use to the local population. The people therefore do not cooperate in the plantation programme which are evident failures. As much as 95 per cent of the plantations in fact have failed. Bereft of the tree cover, the Himalayan hills are eroding heavily, even coming down in disastrous landslides. Of course, it is not just the fodder, but also the fuel, fruit, fibre and fertilizer needs of the farmers that have suffered a great setback with no replacement on horizon.

FERTILITY OF FIELDS

Fertile land is one of our most precious resources which is being indiscriminately destroyed. While undertaking development, for instance, we should attempt as far as possible to match the land use with the land capability. But this is being grossly violated, so that the Indian Petrochemicals complex at Baroda, which should have been located on relatively useless land has been located on the most fertile and productive land of the locality. So also, the Tehri dam colony in Tehri-Garhwal is situated on the most fertile paddy land, never used by the local people for housing purposes who always locate their villages on the less fertile hill slopes.

Another serious cause of loss of fertile land has been the water logging of black cotton soil under irrigation. This heavy soil becomes quickly water-logged unless very carefully

planned drainage is provided, and the water channels preferably lined. But this has never been done and water-logging has led to extensive loss of fertile land in many parts of the country. An estimate from the Pravara Canal of Maharashtra by the local Agricultural University puts this loss at as high as 30 per cent of all land in the command area. Similar problems in the Tawa aicut area of Madhya Pradesh and Ghataprabha Malaprabha canals of Karnataka have sparked off major agitations by farmers. A slogan of the Tawa aicut agitation, very appropriately, is that fertile soil cannot be manufactured in a factory.

RESOURCES OF THE EARTH

This opens up a critical issue that needs very serious thinking. The bounties of our nature have been taking care of a great deal of the basic requirements of our vast population. Our factories can never substitute for them, nor can modern intensive agriculture. Having destroyed the fish stocks of the sea, we cannot develop modern poultry industry to substitute for this protein. Having destroyed fuelwood, we cannot provide electricity or kerosene as fuel to our rural population. Having destroyed bamboo, we cannot provide cement and steel for the millions of rural houses that we need. Having destroyed the fodder base of the livestock, we cannot

Having destroyed fertile land, we cannot generate new irrigation projects or fertilizer plants at a sufficient pace to replace the losses.

We must therefore take very serious care not to destroy the base of our natural resources. For on this base depends the quality of life of the vast bulk of our population, and this base can be destroyed only at the risk of impoverishing this population even further.

The industrial base that we are developing while destroying these resources has also been totally unable to solve our problem of generating productive employment for the population. For it is estimated that the creation of each new job in industry needs an investment of a lakh of rupees, and we simply do not have the resources to generate the needed jobs through this route.

We must therefore seriously reconsider our development strategy, and learn once again to live in harmony with our natural resources. And we must create employment for the rural population through programmes like the Employment Guarantee Scheme of the Government of Maharashtra to recreate the green mantle of the Indian sub-continent.

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THE DESIGN OF RURAL ENERGY CENTRES

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Lecture 3.3
Rural Technology Course

THE DESIGN OF RURAL ENERGY CENTRES

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ABSTRACT

Need-oriented, self-reliant and environmentally-sound development demands that the design of rural energy centres must proceed step-wise from energy consumption patterns to energy needs to technological options to selection of energy sources and devices to integration of these sources and devices into a system. The procedure is illustrated with Pura village as a concrete example. There is first a description of Pura's energy consumption pattern, and its energy needs and energy resources. In the absence of a rigorous methodology for solving the fundamental problem of designing rural energy centres, viz., what is the optimum way of harnessing i energy sources with the aid of j devices to achieve k energy-requiring tasks?, a heuristic approach based on second law efficiencies is used. The result is a design for a rural energy centre for Pura. The first phase of such a centre involves a community-scale biogas plant to meet the energy needs of cooking, domestic electric illumination, and pumping domestic water, in addition to providing organic fertilizer and producing rice husk ash cement. The Pura exercise is used to formulate several principles of rural energy system integration, viz., mixing, cascading, and combining of sources, spatial task integration and time-sharing. Finally, the general problem of designing rural energy centres is mathematically formulated. The formulation highlights important date gaps which must be filled before rigorous rural energy system designing can be achieved.

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INTRODUCTION

The growing realization that the benefits of growth in developing countries have not "trickled down" to the rural poor has stimulated global irterest in technologies for rural development. In particular, problems of rural energy have attracted widespread attention. ASTRA has been compelled, from its very inception, to interest itself in rural energy by the constant complaint of the villagers with whom it was in contact that "fuel" was one of their most pressing problems. Several difficulties, however, came to the fore immediately. Firstly, there was hardly any information at all on energy consumption patterns now prevalent in villages. Secondly, even if the information had been available, a proven methodology for rural energy planning was lacking.

Thus, in the villages in which it is working, ASTRA had to start from "zero", develop an energy data base and then formulate an energy strategy for implementation. ASTRA is now entering the implementation phase for a rural energy centre.

BASIC APPROACH

Rural energy planning is based on an approach consisting of the following steps:

(1) elucilation of current rural energy consumption patterns;
(2) translation of these patterns into a set of energy needs arranged according to priority;
(3) consideration of the feasible technological options, including the traditional ones, of satisfying these energy needs;
(4) selection of the "best" option for satisfying each category of need;
(5) integration of the selected options into a system.

This paper describes the use of this approach for the design of a rural energy centre for Pura village.

PURA'S ENERGY CONSUMPTION PATTERN

A detailed study on energy consumption pattern for Pura village was conducted starting from scratch based on repeated visits, observations and measurements.

The energy-utilizing activities in Pura are:- (1) agricultural operations (with ragi and rice as the main crops), (2) domestic activities, viz., grazing of livestock, cooking, gathering firewood and fetching water for domestic use including drinking, (3) lighting, and (4) industry (pottery, flour mill and coffee shop). These activities are achieved with the following direct sources of energy: human beings, bullocks, firewood, kerosene and electricity.

An aggregated matrix showing how the various energy sources are distributed over the various energy-utilizing activities is presented in Table 1 in the units appropriate to the sources.

The matrix yields the following ranking of sources (in order of percentage of annual requirement): (1) firewood - 89%; (2) human energy - 7%; (3) kerosene - 2%; (4) bullock energy - 1%; (5) electricity - 1%. The ranking of activities is as follows: (1) domestic activities - 91%; (2) industry - 4%; (3) agriculture - 3%; (4) lighting - 2%.

Some important results of this analysis are: (i) 77% of energy in agriculture is derived from animate sources; (ii) Most of energy is from renewable sources, but at an exhorbitant cost - low levels of agricultural productivity and large amounts of human energy for gathering firewood. Fetching water (1.5 hours at 1.6 kms per day) utilizes a great deal of human energy, (iii) 46% of human energy goes towards grazing livestock. Only 29% of houses are electrified.

PURA'S ENERGY NEEDS

The above pattern of energy consumption constitutes the data base for formulating an energy plan for Pura. This objective is facilitated by representing energy consumption

in terms of end-uses or tasks classified with a physics perspective. Such an approach leads to the identification of the energy requirement of cooking, i.e., medium-temperature heating (95-250°C), as the first priority in rural energy planning.

PURA'S ENERGY RESOURCES

Pura's energy resources position must next be examined. Pura's only internal energy sources are those arising directly, or indirectly, from photosynthesis, i.e., firewood, crop wastes (e.g., rice husk) and animal wastes.

The present pattern of firewood usage is unsustainable for more than a few more years. For firewood to become a dependable resource (instead of a liability), it must be harvested from efficiently managed "energy forests" where fast-growing trees are grown specifically for their firewood output. Even though about 5 hectares of energy forests can yield Pura's present firewood consumption of 217 tonnes per year, because of long gestation times of 3-5 years, they cannot therefore be part of an immediate solution.

In contrast to the relatively long gestation times associated with the growth of energy forests and the development of ethanol production, animal wastes are a major resource which can be tapped within a year. The energy survey indicated that Pura's cattle population of 143 yields about 1.02 tonnes of wet dung per day from overnight droppings alone. This minimum of 370 tonnes of wet dung per year can be anaerobically fermented in a biogas plant to yield at least 35 m^3 per day or 12,775 m^3 per year of biogas (60-70% CH_4 and 30-40% CO_2) with a calorific value of 5340-6230 kcal/m^3.

The two renewable energy inputs flowing into Pura spontaneously are solar and wind energy. Wind data has been obtained at the ASTRA Extension Centre, about 2 kms from Pura. Though the average wind speed is about 15 kms/hour, it can go as high as 30-40 kms/hour for one to two hour intervals.

Electricity and kerosene are both energy sources which are imported into Pura. At present, Pura consumes an average of 30 kwh/day of electricity. (Only 25% of the homes have electric lights and a mere 5% own irrigation pumpsets.) Various constraints on generation and transmission mean that grid electricity must be viewed as a limited resource even if the generation is from renewable sources, e.g., hydel generation.

SELECTION OF SOURCES AND TECHNOLOGIES TO MEET PURA'S ENERGY NEEDS:

The fundamental problem of rural energy planning, and of the design of rural energy centres, can be stated thus: what is the optimum way of harvesting i energy sources with the aid of j devices to achieve k energy-requiring tasks? In other words, if ijk is designated as an energy path by which a source i is utilized with the aid of a device j to fulfil an energy task k, what is the optimum set of energy paths, and the optimum energy flow along each one of this set, to meet the energy needs? An immediate solution is required to meet present needs, but it is also essential to anticipate change, and to develop solutions which cater to the contours of future needs.

A rigorous methodology for solving the fundamental problem posed above has yet to be developed. Pending such an achievment, a heuristic approach has been adopted for Pura's energy needs.

In the case of Pura, the energy-requiring tasks have been listed in Table 2 (medium-temperature heating 95-250°C, low-temperature heating $\sim$ 55°C, lighting $\sim$ 2000°C, stationary power, mobile power, and high-temperature heating $\sim$ 800°C). The energy sources available now in Pura or in the very near future are: energy forests, ethanol, biogas, solar energy, wind energy, grid electricity and kerosene; i.e., i = 7. Despite the limited number of tasks and of sources, a very large number of energy paths can be thought of for going from sources to tasks.

In this context, guidance can be sought from the second law of thermodynamics, and in particular, the concept of second law efficiencies. For a given task, it is the maximization of second law efficiencies that determines the minimization of fuel consumption in the case of consumable fuels, and of capital costs in the case of renewable sources. The maximization of second law efficiencies implies that sources and devices must be matched to the task. This matching is facilitated by two thumb-rules: (a) "Do not use a higher quality source than the task deserves!", and (b) "for the matched source, choose the device which transfers the most useful work/heat!".

Thus, second law efficiencies are a powerful heuristic for selecting the technically "best" energy technologies (sources and devices) for the various tasks that need to be performed. Pending the establishment of a complete table of second law efficiencies, the thumb rules can be used.

The use of the thumb rules leads in the case of Pura to the selection of a very limited set of energy paths, i.e., sources and devices to achieve the tasks corresponding to the energy needs of Pura.

To restrict the alternatives further, additional constraints must be imposed.

The first additional constraint is the necessity of matching the time-dependence of the energy-utilizing task (the load curve for the task) with the time-variation, if any, of the supply of energy from the chosen source.

The second additional constraint concerns the development criterion of self-reliance. Imports of energy into the village can be ruled out in the first iteration, and permitted only when it is found that internal energy sources and those coming into the system "free" (solar, wind, flowing water) cannot meet the energy needs.

The third additional constraint arises from the development criterion of environmental soundness. To sustain

development over the long run, renewable sources of energy must be chosen.

The fourth additional constraint is that of power. This constraint becomes relevant whenever a task k must be completed within a certain time t_k, e.g., ploughing or harvesting or grain drying.

The fifth additional constraint is that of availability of the technologies.

The additional constraints described above narrows down the choice drastically. In the case of Pura, the choice gets restricted to: (1) biogas and biogas burners for medium-temperature heating, (2) electricity and incandescent lamps (or fluorescent tubes) for lighting, (3) wind (whenever available) and windmills for stationary power (particularly water-lifting), (4) biogas and biogas engines for stationary power (including water-lifting at sites close to biogas plant).

With regard to those energy-utilizing tasks in Pura which now involve expenditures of human energy (Table 2), gathering firewood and fetching water are directly related to cooking fuel and water supply respectively. Hence, by meeting the energy needs of medium-temperature heating and stationary power for domestic water lifting, the expenditure of human energy on gathering firewood and fetching water can be wholly or partly reduced.

A RURAL ENERGY CENTRE FOR PURA

Notwithstanding the technical attractiveness of establishing a complete rural energy centre as a "one-shot affair", there is an important sociological reason why technological innovations must be introduced a few at a time and not all at once. Each innovation constitutes a perturbation imposed upon the village system which is forced to go into a transient response before settling down to a new state of equilibrium. The phased growth of a rural energy centre also facilitates the mid-phase and inter-phase modifications of total system design which are certain to become necessary

because of inadequate a priori understanding of villages and/or complex energy systems.

With this perspective, a community biogas system is envisaged as Phase I of the proposed rural energy centre for Pura. Biogas has been the first choice because it addresses itself to the first priority energy task in Pura, viz., medium-temperature heating (95-250°C) for cooking.

The design of the system has been guided by the fact that, even assuming a minimum yield of 0.034 m^3/kg fresh dung, a 42.5 m^3/day plant can provide a surplus of 11 m^3/day of biogas after meeting all the cooking energy needs of all the households in Pura. This means that the surplus gas must be utilized to yield economic returns which can completely subsidize the "free supply" of non-metered piped biogas to all the houses between fixed hours determined from present cooking patterns.

It is proposed that the excess gas will be used to run a 5 HP biogas engine, and that the $5\frac{1}{3}$ hours engine time will (1) pump the daily water requirements of the biogas plant, and thereafter, the domestic needs of the village - 20 mins; (2) drive a generator to supply electricity between fixed hours - 3 hours/day - to illuminate the non-electrified houses;* (3) provide motive power for a ball mill to grind for 2 hours/day rice husk ash (a waste product) and lime and produce saleable cement.

In addition, the plant will yield every day 1960 kg of liquid slurry which dries out with a nitrogen content of 1.9% which is double the nitrogen content of fresh dung dried in the open air.

Thus, in the first phase, it is proposed to: (1) pipe cooking fuel to all the homes in Pura, (2) provide electric lighting to the presently non-electrified homes, (3) pump the

* This electricity will be charged for at the usual electricity board rates. Despite this, the households will have to spend only about 60% of what they now spend on kerosene lamps.

domestic water requirements of the village to an overhead storage tank. In this process, the drudgery of firewood gathering for cooking fuel needs will be eliminated completely, and that of obtaining water will be alleviated.

The subsequent phases of the rural energy centre for Pura are being considered. Phase II may attempt to meet the total energy needs for low-temperature heating (of water for bathing) and partial needs of water lifting with windmills. In addition, the initiation of an energy forest will be considered. Phase III will seek to address itself to motive power needs perhaps through producer-gas and/or ethanol engines.

TOWARDS A MATHEMATICAL APPROACH TO RURAL ENERGY CENTRES

The case study of Pura has been used as an illustrative exercise to reveal the nature and complexity of the problem of rural energy centres and to indicate a heuristic approach. Like all villages, Pura is both unique and typical. But, the energy problem of Pura is bound to be fundamentally different from the problems of a village in the cold mountains, windy coasts, forests or deserts.

To handle this variety of villages, and therefore of rural energy problems, it would be advantageous to develop a mathematical approach to rural energy systems. Towards this end, a preliminary attempt at a mathematical formulation of the problem of rural energy centres is indicated below.

As stated earlier, the fundamental problem of designing a rural energy centre for a particular village is to find the optimum way of using its p accessible sources in n possible devices to perform the p tasks corresponding to its energy needs.

The first constraint is that the total energy supplied by the sources should be equal to the requirements of the tasks. Defining A_k as the total energy requirement (e.g., in

kcal) of the kth task, the condition is that

$$A_k = \sum_{i=1}^{m} \sum_{j=1}^{n} r_i \eta_{ijk} x_{ijk} \qquad (1)$$

$$k = 1,2,\ldots p$$

where r_i is the energy equivalent (e.g., calorific value) of the source i, η_{ijk} is the first law efficiency* for the path ijk defining the ratio of the energy output to the energy input, and x_{ijk} the quantity of resource i used via device j to perform task k.

The second constraint is that there is an upper limit for all local energy sources. Defining R_i as the maximum energy locally available per annum from the ith energy source ($i = 1,2\ldots m'$, where the m' local energy sources are a sub-set of the set m of all energy sources), the condition is that

$$R_i \geq \sum_{j=1}^{n} \sum_{k=1}^{p} x_{ijk} \qquad (2)$$

$$i=1,2, \quad m'$$

The third constraint is that some tasks have definite power requirements. If P_k is the maximum power required by the individual user of a device performing the kth task and P_{ijk} is the maximum power available for this task from a source i via device j, the condition can be written thus:

$$x_{ijk} = 0 \text{ if } P_{ijk} < P_k \qquad (3)$$

It is also essential that the sum of the power outputs of the ith energy source through all the paths ijk should not exceed the maximum power P_i^{max} which this source can develop,

* η_{ijk} is assumed here to be independent of x_{ijk}, i.e., there are no efficiencies of scale.

i.e., the condition is

$$P_i^{max} \geq \sum_{j=1}^{n} \sum_{k=1}^{p} P_{ijk} \quad \text{(output)} \qquad (4)$$

The design of the rural energy centre can be based on several objectives. The obvious one is minimization of the total annual cost, C, of the rural energy centre. If C (cap) and C (op) are the annual charges arising from the capital investment and operational requirements respectively, then the objective function which has to be maintained is

$$C = C\ (cap) + C\ (op)$$

As a first approximation*, the annual costs arising from the capital investment and operational charges for source i can both be assumed to be proportional to the quantity of source i which is utilized, i.e.,

$$C\ (cap) = \sum_{i=1}^{m} c_i\ (cap) = \sum_{i} \sum_{j} \sum_{k} a_{ijk}\ x_{ijk} \qquad (5)$$

and

$$C\ (op) = \sum_{i=1}^{m} c_i\ (op) = \sum_{i} \sum_{j} \sum_{k} b_{ijk}\ x_{ijk} \qquad (6)$$

where the constants of proportionality, a_{ijk} and b_{ijk}, represent the annual capital charges and operational costs respectively per unit quantity of source i used via device j to accomplish task k.

The preference for local, renewable sources can be introduced by using multipliers thus: $\alpha_i >> 1$ for non-local sources and $\beta_i >> 1$ for non-renewable sources. That is

$$C\ (cap) = \sum_{i=1}^{m} \alpha_i \beta_i \sum_{j=i}^{n} \sum_{k=1}^{p} a_{ijk}\ x_{ijk}$$

* The approximation is completely valid when the annual capital and operational costs arise from devices whose number is proportional to the quantity of energy source used, e.g., when there is one device per family. It is also valid when the scale of devices used in villages is in a range within which there are hardly only economies.

The fundamental problem of rural energy system design can now be stated:

Minimize C where

$$C\ (cap) = \sum_{i=1}^{m} d_i \beta_i \sum_{j=1}^{n} \sum_{k=1}^{p} \frac{a'_{ijk}}{\epsilon_k} x_{ijk} + \sum_{i=1}^{m} \sum_{j=1}^{n} \sum_{k=1}^{p} \frac{b'_{ijk}}{\epsilon_k} x_{ijk}$$

Subject to the following conditions:

(1) $\sum_{i=1}^{m} x_i \sum_{j=1}^{n} \eta_{ijk} x_{ijk} = A_k$ (Needs satisfaction)
$k = 1,2, \ldots P$

(2) (Resource availability)

$$r_i \sum_{j=1}^{n} \sum_{k=1}^{p} x_{ijk} \leq R_i$$

$i=1,2,\ldots.m' < m$

(3) (Total power availability)

$$\frac{r_i}{d_i} \sum_{k=1}^{p} \frac{P_k}{A_k} \sum_{j=1}^{n} x_{ijk} \leq P_i^{max}$$

(4) $x_{ijk} \geq 0$ for all i,j and k

The following set of conditions:

$x_{ijk} = 0$ if $P_{ijk} < P_k$ (Power availability for individual devices)

$\eta_{ijk} = 0$ if periods of source supply and demand do not overlap,

can be introduced into the problem as on a priori check and by setting the values of corresponding x_{ijk} 's and η_{ijk} 's equal to zero.

The above approximation of the general problem has a linear objective function (costs) and linear constraints.

Further, the variables are non-negative. Hence, it is a linear programming problem* which can be solved by simplex or revised simplex procedures. It is in fact a three-dimensional transportation problem.

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* If, however, there are marked economies and efficiencies of scale even for the scales of devices reasonable for villages, then the linear approximations are no longer valid, and the problem becomes a non-linear programming exercise.

TABLE 1 : ENERGY SOURCES AND ACTIVITIES

	Agri-culture	Domes-tic	Light-ing	Indu-stry	Total
Human hours	34848 (12%)	255506 (80%)	-	20730 (8%)	311084 (8%)
(Man hours)	(19914)	(82376)	-	(16485)	118775
(Woman hours)	(14934)	(113928)	-	(4245)	113107
(Child hours)	-	(59202)	-	-	59202
Bullock hours	5392	-	-	-	5392
Firewood (Kgs)	-	207807 (96%)	-	8930	216737
Kerosene (Litres)	-		1938 (93%)	156	2094
Electricity(KWh)	7264	-	3078	820	11162

TABLE 2:

End-use	Input energy (Kcal x 10^6)	Efficiency %	Output (Kcal x 10^6)
1. Heating (95-250°C)	688.9	5	34.4
2. Heating (~ 55°C)	112.4	5	5.6
3. Heating (~ 800°C)	23.8	5	1.2
4. Lighting (Electrical)	2.7	10	0.3
5. Lighting (Kerosene)	17.4	1	0.2
6. Mobile Power	12.4	?	?
7. Stationary Power	7.0	80	5.6
7.1 Water lifting	6.3	80	5.0
7.2 Flour milling	0.7	80	0.6

Human Activity	Annual Energy Expenditure	
	Hours	(Kcal X 10^6
1. Domestic	255,506	50.8
1.1 Livestock grazing	117,533	23.4
1.2 Cooking	58,766	11.7
1.3 Firewood gathering	45,991	9.1
1.4 Fetching Water	33,215	6.6
2. Agriculture	34,848	8.0
3. Industry	20,730	5.0
Total	311,084	63.8

KAS:13.9.79

WIND ENERGY AND ITS USES

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Lecture 3.4.4
Rural Technology Course

1. WIND AND ITS USES

1.1. Wind and their Distribution

Non-uniform heating of the atmosphere due to solar radiation sets up convective motions in the atmosphere. This motion near the ground is the wind. Only a small fraction (about 2%) of energy in the incident solar radiation is converted into the kinetic energy of atmospheric motion. But, this energy is still very large and even if we could extract a small fraction of it, it would supply a significant part of our energy requirements. Further, the energy is distributed throughout the atmosphere and hence could in principle be extracted wherever the need for energy exists. But, the intensity of the wind energy is rather low and thus devices for extracting this energy will be large and it is often uneconomic to build these devices. A detailed study is required in every location before one could recommend a windmill there.

1.2. Measurements of Windspeed

Windspeed is measured by an anemometer, which is generally a rotating device whose R.P.M. is proportional to windspeed. The cup anemometer used by meteorologists is a typical example. The anemometer is mounted on a tower so that the instrument is about 10 meters above the ground. A typical wind trace obtained this way is shown in Fig. 1. It is noticed that the windspeed is a highly fluctuating quantity exhibiting

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1. WIND AND ITS STRUCTURE

1.1 Winds and their distribution

1.2 Measurement of windspeed

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1.4 Analysis of wind data

1.5 Problems of harnessing wind power

2. WINDROTORS AND THEIR CHARACTERISTICS

2.1 Performance parameters

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significant fluctuations within a period of the order of a minute. However, windspeed averaged over a few minutes varies only slightly over the period of an hour. It has become general practice to average the windspeed over a few minutes and define it as the average windspeed during one hour. The windspeed thus defined varies over a day as, for example, in Fig.3.

1.3. Power in a Steady Wind

One may estimate the power in a steady wind easily. If we consider an area A normal to the wind, the rate of flow through this area is clearly ρU^A where U is the windspeed and ρ is the density of air. The kinetic energy of this fluid is $U^2/2$ per unit mass and thus the power, which is the rate of transport of energy over the area, is $\rho U^3 A/2$. Fig. 2 shows the power for a unit area in a steady wind at various values of V. The air density, ρ, has been assumed to be the standard sea level value. The above power cannot all be extracted by a practical device. If we assume that one may extract about 10% of this power, we have an estimate of useful power from a wind to be $0.1 \rho U^3 A/2$ which is about 5 W/m^2 at 15 km/hr. 15 km/hr is a typical windspeed under Indian conditions (for e.g., yearly mean wind at Bangalore is about 14 km/hr) and a 50W windmill will thus have to intercept about 10 m^2 of wind. Thus windmills for even small powers are rather large under Indian conditions.

1.4. Analysis of Wind Data

Windspeed data extending over at least one full year is needed for an assessment of the windpower potential of a given location. A useful way of presenting this data is to plot the monthly mean windspeed against the month as in Fig. 4. This figure shows the large seasonal variation of winds at the location (Bangalore). When it is realised that power in a wind varies as the cube of windspeed, it is clear that a large part (about 90%) of available energy in the wind at this location is available within May to September - the monsoon season. This pattern (which is typical of a large part of India) complicates the problem of exploiting windpower.

Another useful plot obtained from the same wind data is shown in Fig. 6. The figure shows the distribution of energy over the range of windspeeds at the location. It is seen that a large part of the energy is available in the range of windspeeds above the mean. Fig. 5 shows another way of analysing the same data. This curve (called the wind-duration curve) gives the number of hours in a year for which the windspeed exceeds a given value. For example, Fig. 5 indicates that windspeeds above the mean are present for less than half the number of hours in a year.

Analysis of this type as well as others (like the frequency of windless periods of various durations, maximum wind at the location etc.) are useful in answering many questions that arise when one contemplates designing systems

for exploiting wind energy.

1.5. Problems of Harnessing Wind Power

From the previous sections it is clear that the intensity of wind energy is low and further its availability varies greatly over the year. As a consequence, devices extracting windpower will be large (and thus tend to be expensive) and their output will vary greatly over time. Because storing energy in any form is difficult, it is necessary to find suitable uses for the fluctuating output of wind power devices. Pumping water is one use where output variations can be tolerated to a great extent and appears to offer one of the best uses for wind power. Small scale electricity generation (with battery storage) may be useful in remore locations. Large scale extraction in favourable locations is also a possibility which is still to be explored in detail.

Apart from the performance problems above, the windmills pose a difficult structural problem. Windmills are large structures because they have to extract useful energy from low winds which have a small energy density. But windspeeds occasionally reach very high values (often over five times the mean at any location) and because loads increase rapidly with windspeed (roughly as the square of windspeed) the windmills are subjected to very large loads (of the order of 25 times the mean) associated with these short duration bursts of windspeed. Building in enough strength for withstanding these loads tends to make the windmills very expensive. To avoid this

various schemes of reducing the loads on windmills in high winds (like slowing or stopping the rotor, turning the rotor away from wind, furling sails, etc.) are in use. Inspite of these, windmills occasionally suffer damage in high winds and problems in these directions call for a very careful analysis so that the probability of failure is acceptably low.

2. WINDROTORS AND THEIR CHARACTERISTICS

2.1. Performance Parameters

Though it is possible to extract wind energy by using many types of devices (such as oscillating airfoils, concentrating ducts with rotors , etc.), the ones that appear to be most promising are simple rotors without ducts. One way characterise the performance of a rotor by its torque Vs speed relationship with windspeed as a parameter. However, it is more convenient to present the performance in dimensionless variables. We thus define the torque coefficient, C_Q, and tip-speed ratio, λ , of a windrotor as below:

$$C_Q = Q/\tfrac{1}{2} \quad V^2 S R \qquad (2.1)$$

$$\lambda = 2\pi NR/60V \qquad (2.2)$$

In the above Q is the torque generated by the rotor in a wind of speed V at a rotation speed N. ρ , S and R are respectively the air density, rotor projected area and radius. In terms of these dimensionless variable, the performance of

a rotor is expressed as a relation between C_Q and λ . This relation depends only slightly on the Reynolds number for the rotor VR/ν , where ν is the kinematic viscosity.

It is often more convenient to use a power coefficient, C_P as

$$C_p = \frac{P}{\frac{1}{2}\rho V^3 S} \qquad \ldots(2.3)$$

where P is the power generated by the rotor. It is easily seen that C_P as defined here is the product of C_Q and λ defined earlier.

2.2. Types of Windrotors

Based on their geometry, Windrotors can be classified as horizontal-axis and vertical axis types. The horizontal axis rotors turn about a horizontal shaft and thus have to be oriented to face the wind at all times. Vertical axis types are omnidirectional and are thus mechanically simpler. The Savonius and Darrieus rotors are examples of vertical axis types while the propeller type is an example of the horizontal axis type.

The Savonius Rotor: This rotor, invented around 1930, consists of a pair of semi-circular cylinders mounted between a pair of circular end plates is an over-lapping configuration as shown in Fig. 7. The main attractions of this rotor are a combination of (a) simplicity, (b) good starting torque, (c) moderate efficiency of over 20%. Much experimental work

has been done in the development of Savonius type rotors. Results of experimental studies of rotors with variations in the number of buckets, bucket profile and the overlap of the buckets are currently available. It is now clear that a 2 bucket Savonius rotor with buckets of non-circular shape (with curvature more near the leading rather than trailing edges of the buckets) and with circular end-plates just enclosing the buckets is about the best among them. A way of constructing such rotors is to use strong end plates and string wires between them and clothe the strings by sails of canvas. This method has been successfully used for a rotor of 2.5m dia. and about 3m. height.

The Darrieus Rotor: This rotor resembles an egg-beater. Typically such a rotor consists of two blades of symmetrical airfoil section. Each blade is bent into an arc and its ends are fixed to two points some distance apart along a vertical shaft such that when the whole unit turns about the shaft, the blade cross-sections move along their chords (with zero incidence). It can be seen from Fig. 8 that such a rotor, when placed in a wind, will produce a driving torque if the rotor is already turning at a reasonably large tip-speed ratio (say 3). But, at low tip-speed ratios, the blades operate under stalled conditions and hence the torque of the rotor is small and may even be negative and thus such a rotor, without a suitable controlling device, cannot be coupled to a load requiring a large starting torque, (like a positive displacement

water pump). These rotors are being developed for producing electric power.

The Horizontal-axis Rotors: These generally consist of a horizontal shaft carrying a rotor with a number of radial blades (generally between 2 and 12). The blades range from an optimally twisted shape of airfoil cross-section to simple triangular fabric sails supported by radial rods and wires. Sheet metal blades of a cambered cross-section are also common. These rotors can be designed to run efficiently at tip speed ratios in the range of 1.5 (for sail-type rotors) to about 8 (for airfoil bladed rotors). The low-speed rotors have a good starting torque and can be coupled to pumps. The high-speed rotors are more efficient and are more suitable for driving electric generators.

2.3. Characteristics of Windrotors

One may specify the performance of a rotor by plotting its power coefficient, C_p, against the tip-speed ratio, λ, as defined in Sec. 2.1. Fig. 9 shows the characteristics of many different rotor types. The ideal efficiency indicated in the figure has been obtained from theoretical considerations, to be considered in Chapter 3. Fig. 9 indicates that ideal rotors designed for high tip-speed ratios achieve a theoretical C_p of 0.59. In practice, well designed horizontal axis rotors employing airfoil blades of excellent surface finish approach this ideal most closely and achieve a C_p of around 0.45 at a λ in the range of 8 to 10. Simple low-speed rotors achieve a

C_P of around 0.45 at a λ in the range of 8 to 10. Simple low-speed rotors achieve a C_P in the range of 0.2 to 0.35 at values of λ in the range of 0.8 to 2.5.

2.4. Fields of Application of Different Windrotors

Historically windmills have been used for milling grain and for pumping water. Small isolated windrotor driven electric generators with battery storage have been used for supplying power for lighting and for radio communication purposes. The first two applications demand a good starting torque and rotors with poor starting torque (like the Darrieus rotor) are generally unsuitable for such applications.

Choice of a rotor for a given type of application is also guided by economic and social considerations. For example, the requirement that a windmill be built and maintained by using simple technologies available in rural areas, generally rules out a high-speed rotor with blades of airfoil section. Again, a large windmill for generating a substantial quantity of power has to be efficient and low-speed rotors are unsuitable for this application.

Thus, the choice of a rotor for a specific application must consider all relevant factors - size of rotor, nature of load, technology desirable in the context of the application and cost. Applications of windmills in India are still too few to permit any generalisations about rotors suitable for India. However, the main application of windrotors in India appears to be for pumping water though some electric power

generation at particularly favourable sites is a possibility. It appears that horizontal-axis sail-type rotors are the most suitable for pumping water. Darrieus and horizontal-axis high speed rotors appear suitable for electric power generation.

3. THEORY OF HORIZONTAL-AXIS WINDROTORS

3.1. Actuating Disc Theory

The purpose of any theory of windrotors is to obtain the $C_P - \lambda$ curve (and hence also the $C_Q - \lambda$ curve) for any rotor configuration. Using such theories one may conveniently study both the limitations and the possibilities of windrotors from the point of view of performance.

The simplest theory of windrotors is the actuating disc theory due to Betz which throws light on the upper limit to C_P. The flow model used in this theory is shown in Fig. 10. Here the windrotor is replaced by an actuating disc which extracts power from the airstream passing through it and hence there is a difference in pressure between its upstream and downstream faces. The freestream of speed V_∞ shows to U at the rotor and to U_1 at downstream infinity. The flow is assumed to be inviscid throughout. We may write the laws of fluid motion applicable to this flow situation as below.

First using Bernoulli's law between sections (1) and (2) upstream of the actuating disc, we have

$$p_0 + \tfrac{1}{2} \rho V_\infty^2 = p + \tfrac{1}{2} \rho U^2 \qquad \ldots\ldots(1)$$

Similarly between sections (2) and (3) downstream of the actuating disc, we have

$$p_o + \tfrac{1}{2} \rho U_1^2 = p' + \tfrac{1}{2} \rho U^2 \qquad \ldots\ \ldots (2)$$

Using (1) and (2) we have,

$$p - p' = \tfrac{1}{2} \rho (V_\infty^2 - U_1^2) \qquad \ldots\ldots\ (3)$$

Using (3) we have an expression for the thrust on the actuating disc which is the area times the pressure difference as

$$\text{Thrust} = \tfrac{1}{2} \rho (V_\infty^2 - U_1^2)\, A \qquad \ldots\ldots\ (4)$$

This must be equal to the difference in the momentum flux between stations (1) and (3),

$$\text{i.e.}\quad \text{Thrust} = \tfrac{1}{2} \rho\, UA\, (V_\infty - U_1) \qquad \ldots\ldots\ (5)$$

From (4) and (5) we get

$$U = \frac{V_\infty + U_1}{2} \qquad \ldots\ldots\ (6)$$

This result indicates that the flow velocity through the rotor is the mean of the flow velocities at the upstream and downstream infinities. If we define an inflow factor, a, by

$$U = (1-a)\, V_\infty \qquad \ldots\ldots\ (7)$$

then, (6) implies

$$U_1 = (1 - 2a)\, V_\infty \qquad \ldots\ldots\ (8)$$

The power extracted by the actuating disc then becomes

$$\text{Power} = \tfrac{1}{2} \rho \, (V_\infty^2 - U_1^2) \, AU$$

i.e. $$\text{Power} = \tfrac{1}{2} \rho \, V_\infty^3 \, A \, 4a \, (1-a)^2 \qquad \ldots\ldots (9)$$

so that

$$C_P = 4a \, (1-a)^2 \qquad \ldots\ldots (10)$$

Maximising C_P with respect to a, we find $a = \frac{1}{3}$ and $C_{P\,max} = 0.593$. This represents the maximum power coefficient for an actuating disc in an inviscid fluid and represents the upper limit of C_P for windmill rotors also.

3.2. Blade Element Considerations

The above theory does not take into account the fact that the windrotor is a rotating device imparting some angular momentum to the fluid passing through it. Further, any realistic windrotor can only have a finite number of blades and thus the flow in the plane of the rotor will not be uniform. One may thus expect a C_P for realistic rotors to be less than the Betz limit derived above. Also, the above analysis provides no information on the rotation speed (related to λ) at which the estimated C_P can be expected. One may obtain some of this missing information using blade element considerations. Here, each blade cross-section at any radius on the rotor is assumed to act as a two-dimensional airfoil working in a local flow situation consisting of an

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undisturbed stream corresponding to that at upstream infinity and an induced flow due to the presence of the rotor. The latter flow can be approximated by the flow due to an actuating disc located at the position of the rotor experiencing the same thrust as the actual rotor. If a higher level of accuracy is required, induced flow at the rotor in a tangential direction could also be included. Fig. 11 shows the flow at a blade section in such a case. It is clearly seen that the components of lift and drag in the plane of rotation contribute to the torque on the rotor and this torque could be estimated by a process of integration over the blade elements. We shall not present the details of this analysis here. However, the main conclusions from such an analysis can be stated below:

(1) A rotor can be designed for best performance at any chosen value of λ. Reasonably efficient rotors can have a λ_{opt} in the range of about 1 to 10.

(2) For a given aerodynamic quality (i.e. maximum lift-drag ratio) of the blade sections, one may choose the number and geometry of the blades and the tip-speed ratio so as to obtain maximum C_P. Small values of C_l/C_d (say 5) imply a large number of blades (around 6) and a low tip-speed ratio (around 1.5) for best C_P (around 0.25). Large values of C_l/C_d (say 100) imply a small number of blades (around 2) and a high tip-speed ratio (over 6) for best C_P (around 0.45).

(3) The shape of the blades for best performance depends much on the optimum tip-speed ratio. Generally, the blade chord is zero at the axis of the rotor, then initially increases rapidly with radius and later decreases slowly. The blade chord makes a large angle to the plane of rotation near the axis while the angle is much smaller near the blade tip.

(4) One may also calculate the off-design performance (i.e. at any $\lambda \neq \lambda_{opt}$) of a rotor using the above theory. For example, one may calculate the starting torque of a given rotor (corresponding to $\lambda = 0$). Such calculations indicate that rotors designed for a small λ_{opt} have a higher ratio of the starting torque to the torque at λ_{opt} as compared to rotors designed for a large λ_{opt}.

3.3. Remarks on Performance

We are now in a position to comment on the performance of horizontal-axis windrotors. The analysis indicates the important role of the aerodynamic quality of the blades (i.e. lift-drag ratio of the blade sections) on the performance of windrotors. The value of lift-drag ratio achievable depends very much on the type of blade construction. A blade can vary from a simple sail supported by a leading edge rod and a trailing edge wire through a sheet metal blade of cambered are profile to an optimally tapered and twisted form of a carefully chosen airfoil section. Thus depending on the type of construction, we can design rotors which ensure the best

performance for that type of construction. The cost of the rotor and its suitability for driving a specific load also depend on the type of blade construction and a final choice of a rotor for a specific application should take all these factors into account.

4. PERFORMANCE OF WINDROTOR-LOAD SYSTEMS

4.1. Common Loads for Windrotors

A windrotor produces mechanical power at its shaft and one may employ this power, in principle, for any of the large number of possible uses. However, because of the large fluctuations in power output from a windrotor, these have been successfully employed only for the small number of applications which tolerate these fluctuations or which handle these fluctuations by using energy storage at acceptable cost. Successful applications to date include heating water, space heating, pumping water, grinding grain and generation of electric power. Of these, pumping water and generation of electric power appear to offer the best prospects in India, and we shall briefly consider these.

Water is essential both for domestic uses and for agriculture and there is a great need to pump water from irrigation ditches, open wells and tube wells in rural areas. One may use simple windpumps for such applications. A simple windpump consists of a windrotor direct coupled to a suitable pumping device (like a chain pump, or archemedian screw) or to

a reciprocating pump using a crank and connecting rod. Such windpumps extract only a small fraction (around 3%) of the energy in the wind crossing the rotor over the year.

A wind-electric generator for small power usually consists of a windrotor connected to an electric generator through a step-up gear box. The generator usually charges a lead-acid battery and is regulated so as to keep the generator voltage and current within certain limits. Large wind-electric generators generally feed into an existing power grid. Small wind-electric generators usually have an overall efficiency of less than 10% including the effects of the battery storage.

4.2. Performance of a Windrotor-Load System

One may obtain estimates of the performance of a windmill-load system analytically by starting from the $C_Q - \lambda$ curve for the rotor and the torque-speed curve for a load. Such estimates are valuable in designing windrotor-load systems for specific applications. They are also useful in assessing the potential benefits of any technical innovations like load-matching devices, etc.

The performance of a windmill-load system is easily evaluated as follows. The torque-speed characteristics of the windrotor for various values of the windspeed can be calculated from the $C_Q - \lambda$ curve for the windrotor. These can be plotted as in Fig. 12. On the same plot, the torque demand of the load against the rotation speed (as reflected at the windmill

shaft, in case there is a gear box between the windrotor and the load) can be plotted. This curve can be obtained by analytical or experimental studies of the load separately. For example, if the load is a pump of displacement, Q, working against a head, H, we can analytically derive the pump torque as

$$T_p = \frac{WQH}{2} + \frac{WKN^2Q^3}{21600\, gA^2} \qquad \ldots\ldots(11)$$

In the above, W is the weight of water per unit volume and A is the delivery pipe area; the hydraulic loss constant for the pump, K, can be estimated using handbooks on applied hydraulics. Torque-speed curves estimated from the above formula are also shown in the Fig. 12. For a chosen windspeed, the intersection between the torque-speed curve for the windrotor and that for the load gives the steady rotation speed. For this speed, the output quantity (water flow in the case of pump) is easily calculated. Similar calculations can be performed at various speeds. When a wind-duration curve for the location is given, one may sum the output in various windspeed bands and estimate the overall output over any chosen time duration (usually a day, a month or a year).

4.3. Matching of Windrotor and Load

Studies of the type indicated in Sec.4.2 often indicate a very poor overall efficiency of the system. For example, windpumps often have an overall efficiency of around 3% even

though the windrotor may have a maximum power coefficient of 0.25 (i.e. 25% efficiency) and the pump may show a maximum efficiency of over 70%. This peculiar behaviour is largely due to the windrotor running at a speed not corresponding to $C_{P\ max}$ except at one windspeed which may be called the design windspeed. Consequently the rotor efficiency is lower than $C_{P\ max}$ most of the time resulting in spillage of power back into the airstream.

One may improve the performance of a windrotor-load system by attempting what may be termed load-matching. Here the principle is to adjust the load torque such that the windrotor runs at constant C_P (equal to $C_{P\ max}$) at all windspeeds. Under such conditions the torque produced by the rotor increases as the square of windspeed while the rotorspeed increases proportional to windspeed. Thus the torque of the rotor rises as the square of its own rotation speed. Thus one may arrange for the load torque to increase as the square of rotation speed matching the torque of the rotor. Then the rotor will run at $C_{P\ max}$ at all windspeeds. This will mean some complexity in the system. For example, one may have to use a suitably programmed variable displacement pump in place of the commonly used constant displacement pump. However, calculations indicate substantial benefits by load-matching (for example, doubling of water flow from a wind-pump is possible) and the complexity may be justified. When one uses

a windrotor for electric power generation, the control system for the generator may be designed paying attention to load-matching in addition to other purely electrical problems.

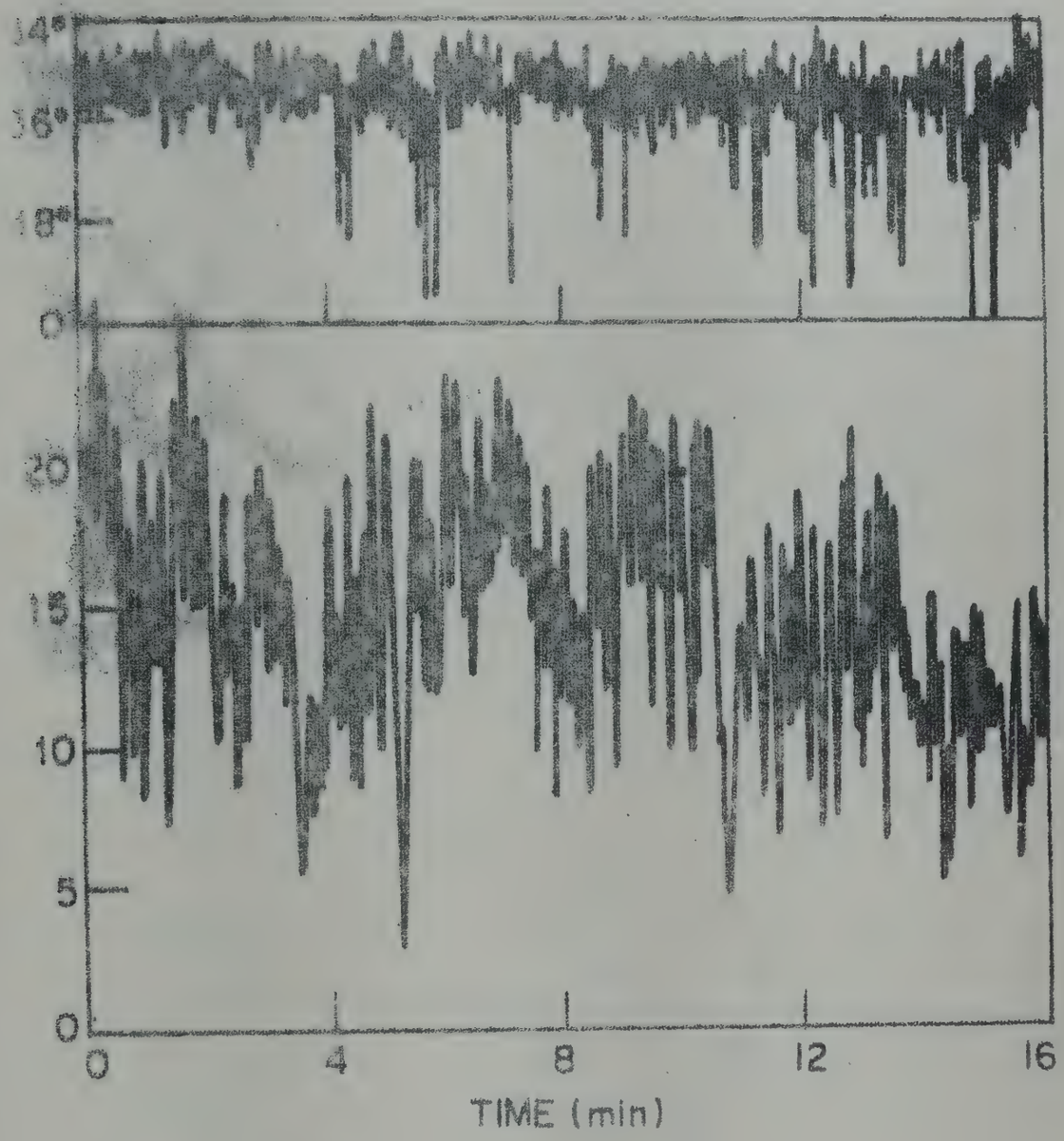
It is interesting to remark here that some loads are naturally matched to a windrotor. A constant displacement pump delivering against the pressure loss of a long pipe is one such load. A rotor churning any fluid converting mechanical energy into heat is another and this has been used for producing hot water using wind power.

4.4. Starting of Windrotor-Load Systems

The main attention in the previous sections was directed towards the performance aspects of simple windmills. Some structural considerations involved in designing windmills to withstand occasional storms was briefly mentioned in Sec. 1.5. We may now mention one other problem which deserves careful consideration - the starting of windrotors with connected loads.

Water pumping windmills generally operate a positive displacement pump demanding a high starting torque. Starting of wind-pumps of this type can be eased by incorporating a small leak at the pump so that the rotor is not loaded at very low rotation speeds. Another solution is to load-match the windrotor using a variable pump displacement. In this case, the pump displacement and hence the load torque decreases to zero at starting.

Electric power is often generated using rotors which have very poor starting torque (because such rotor are designed for a large $C_{P\ max}$ and hence belong to the high-speed category), and starting difficulties may arise even though generators do not electrically load the windrotor at very low speeds. This is because of the considerable friction due to the step up gear box and the generator. Solutions to this problem include variable pitch blades on horizontal axis rotors, auxiliary (Savonius type) rotors on power generating Darrieus rotors and electrical starting using the generator as a motor. On small wind-generators using horizontal-axis rotors, none of these solutions are needed and good starting is obtained by choosing a rotor with adequate starting torque.



PLACE	: I.I.Sc CAMPUS
ANEMOMETER LOCATION	: 10m ABOVE LAB ROOF
DATE	: 19 JUNE 1978
TIME	: 0909 TO 0924 Hrs

FIG. 1. SAMPLE WIND TRACES

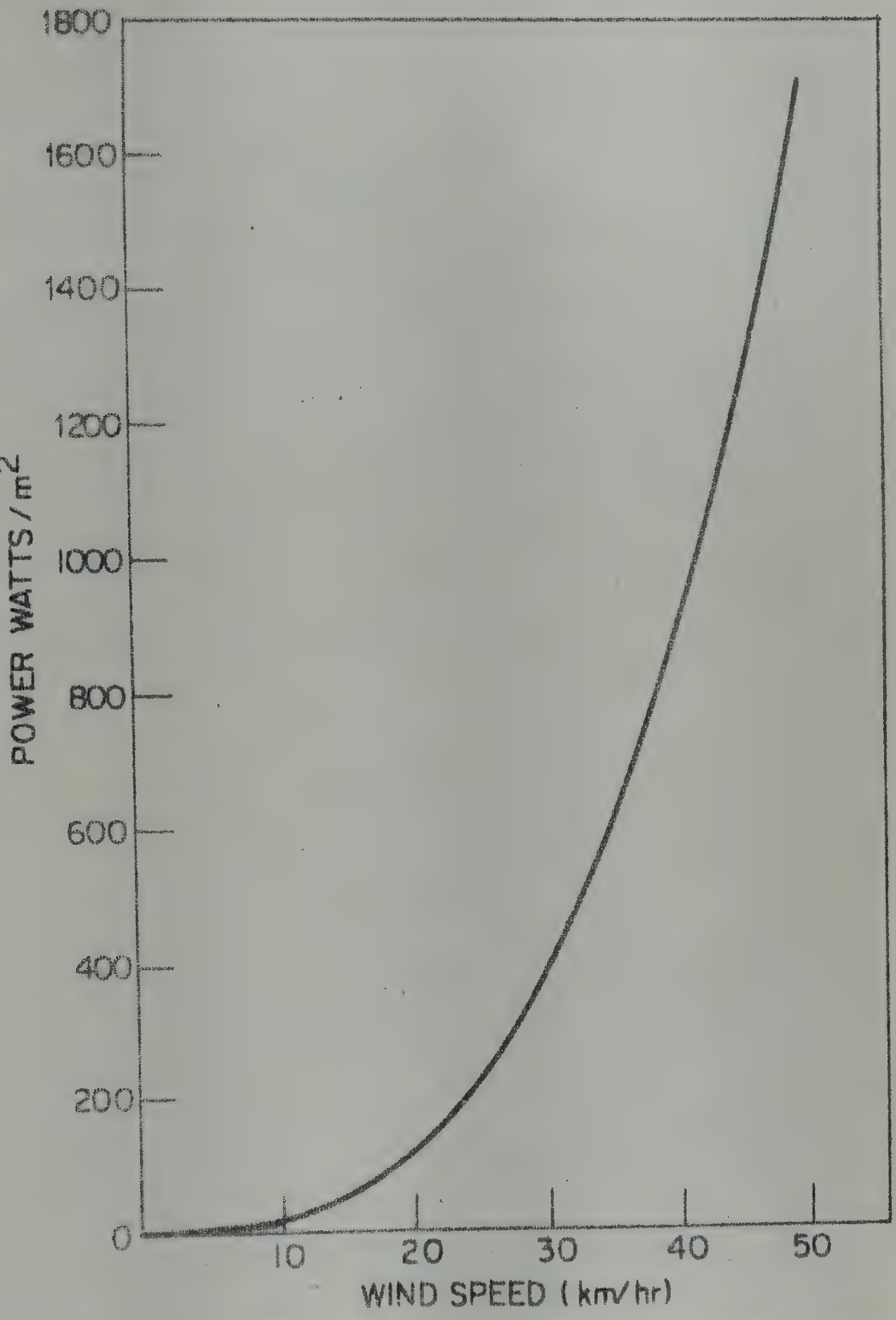


FIG. 2. POWER IN A CONSTANT WIND VELOCITY.

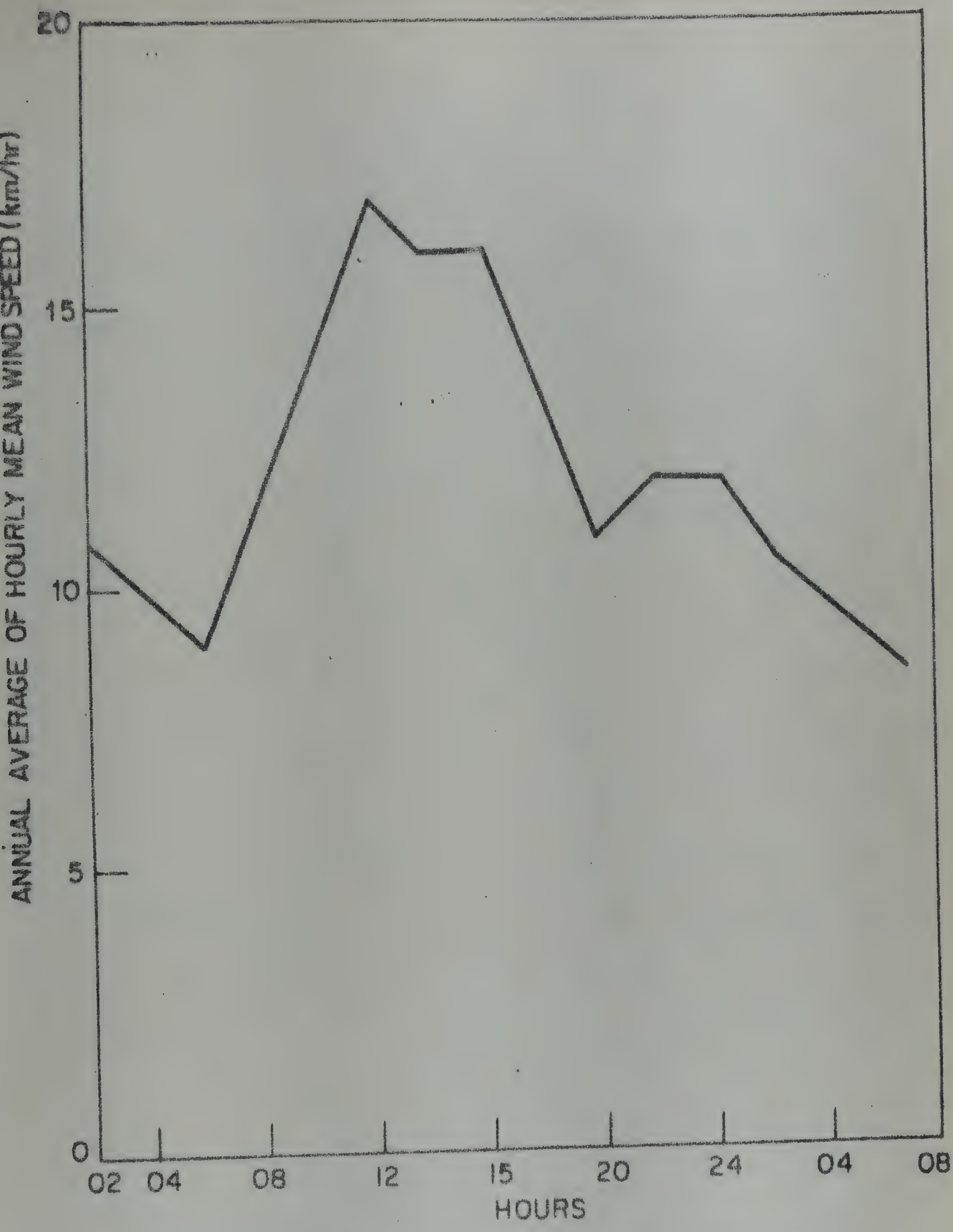


FIG. 3. DIURNAL VARIATION OF WINDSPEED

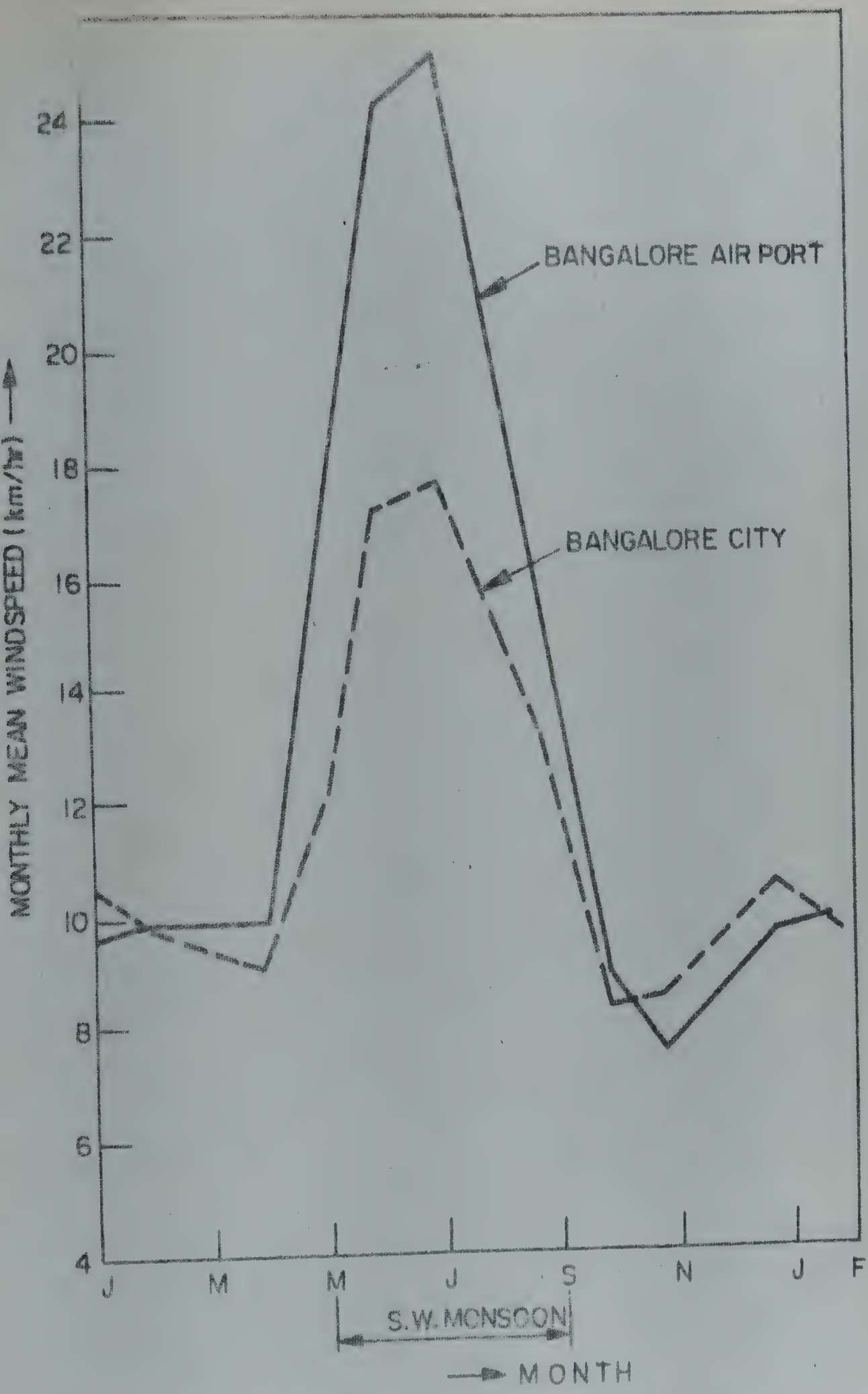


FIG. 4. MONTHLY VARIATION OF WIND SPEED

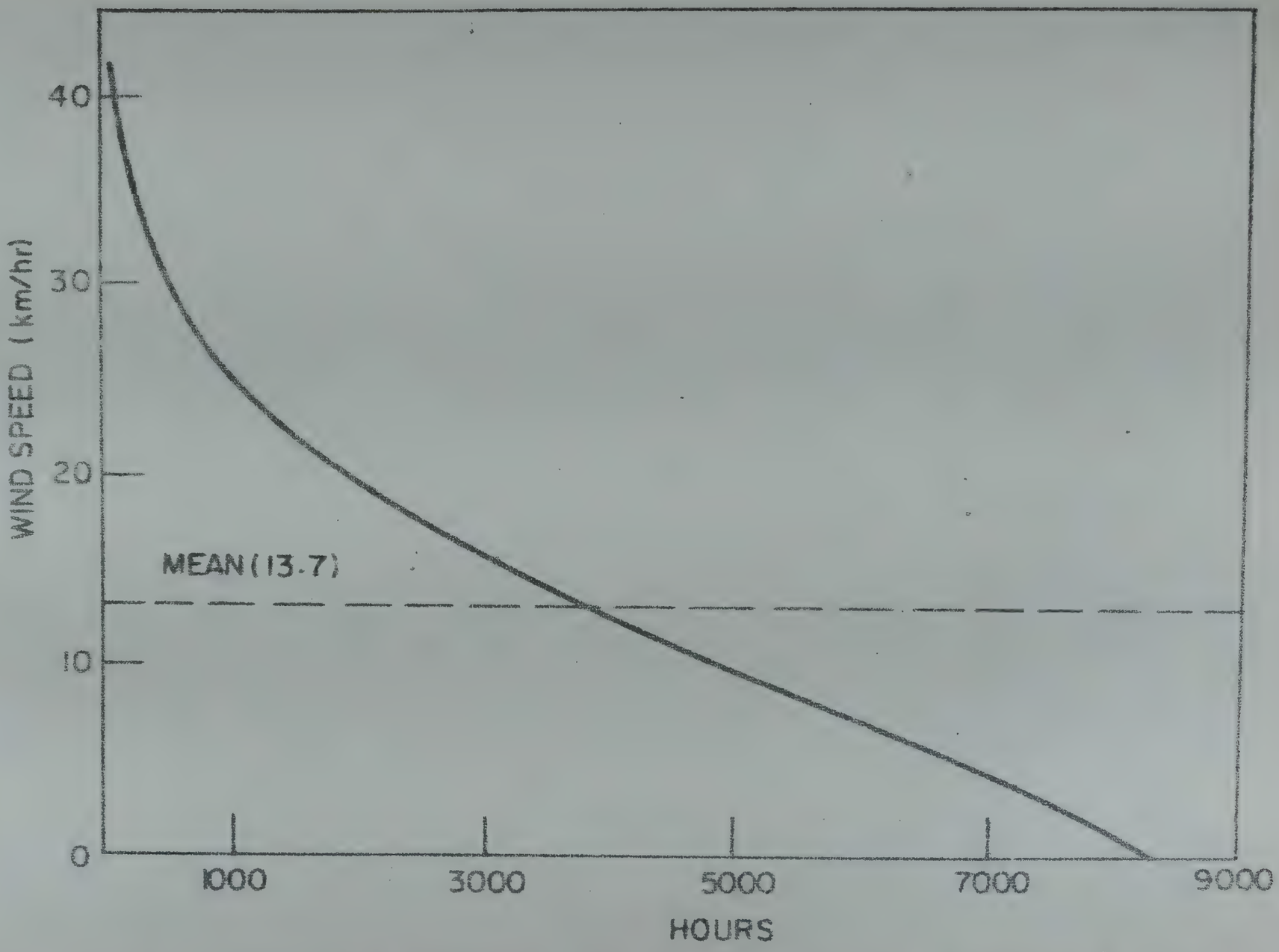


FIG. 5. ANNUAL WIND-DURATION CURVE FOR BANGALORE AIRPORT.

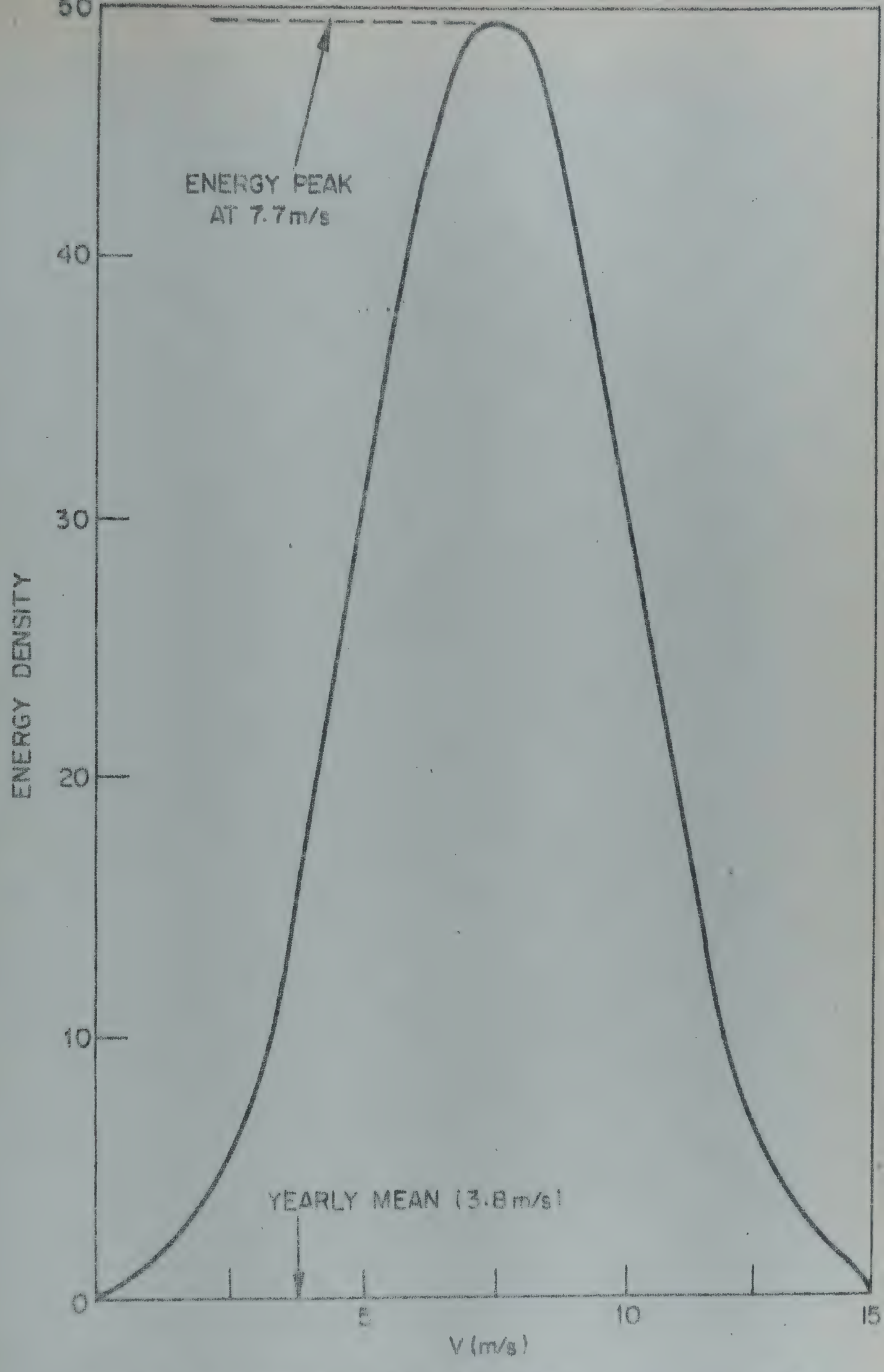


FIG. 6. DISTRIBUTION OF ENERGY OVER THE

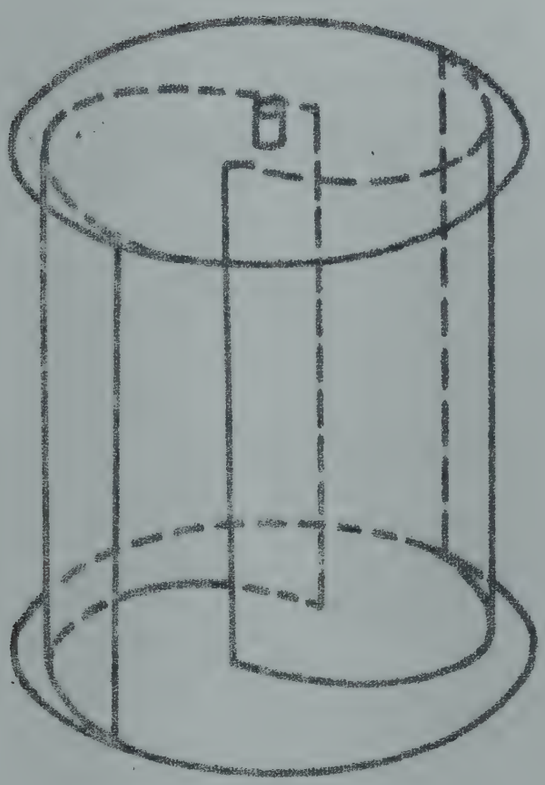


FIG. 7. A SAVONIUS ROTOR

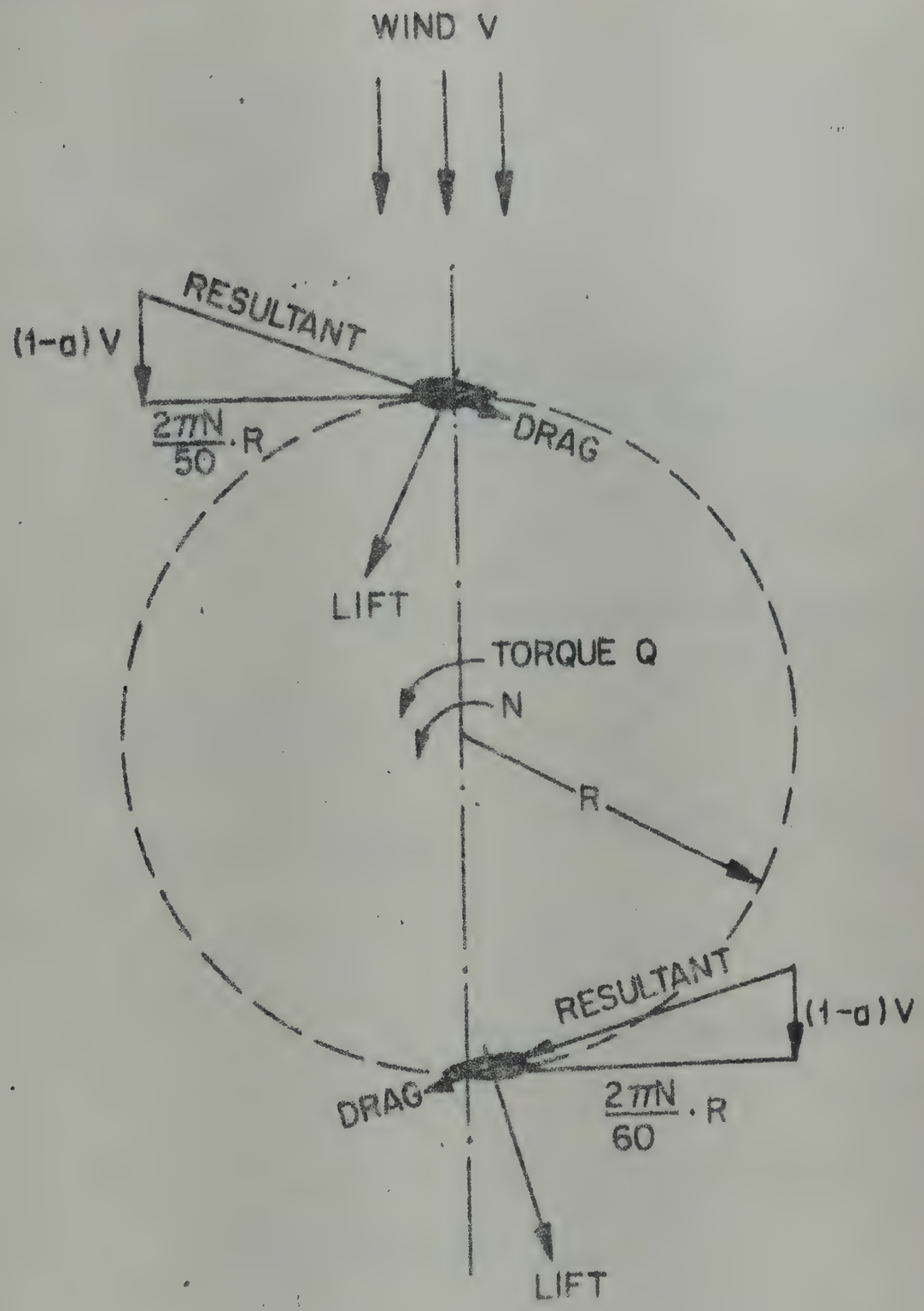


FIG. 8. PRINCIPLE OF OPERATION OF THE DARRIEUS ROTOR.

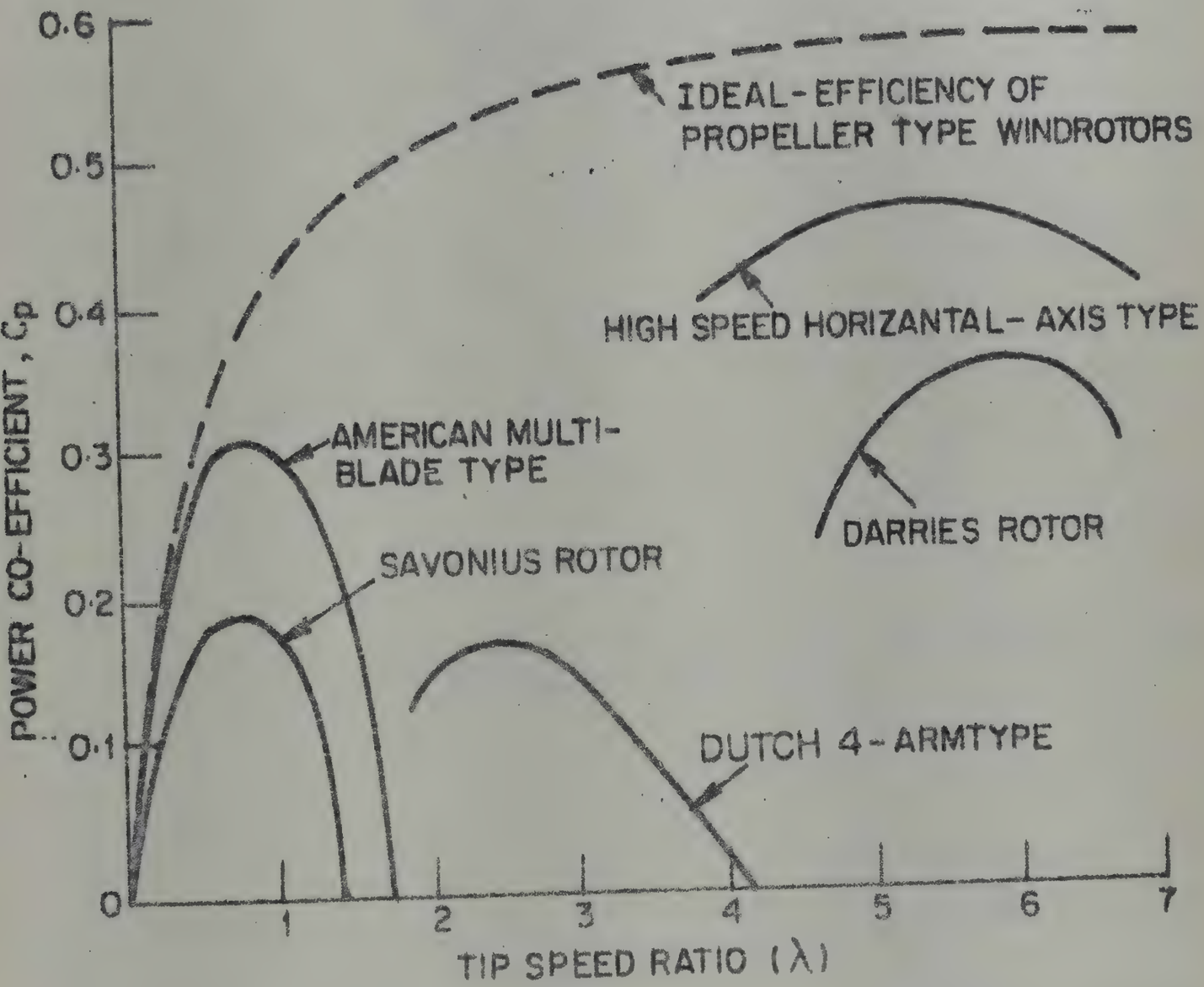


FIG. 9. TYPICAL PERFORMANCE CHARACTERISTICS OF WIND ROTORS

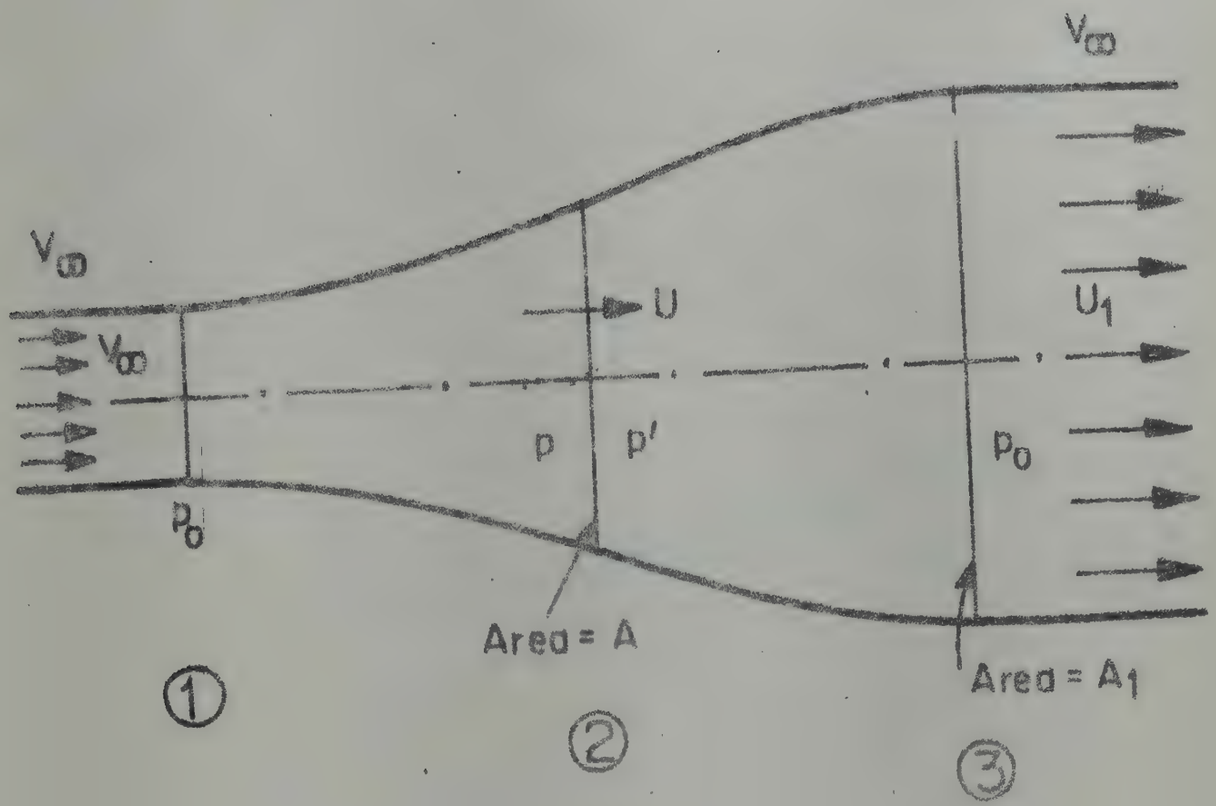


FIG. 10. FLOW MODEL FOR MOMENTUM THEORY

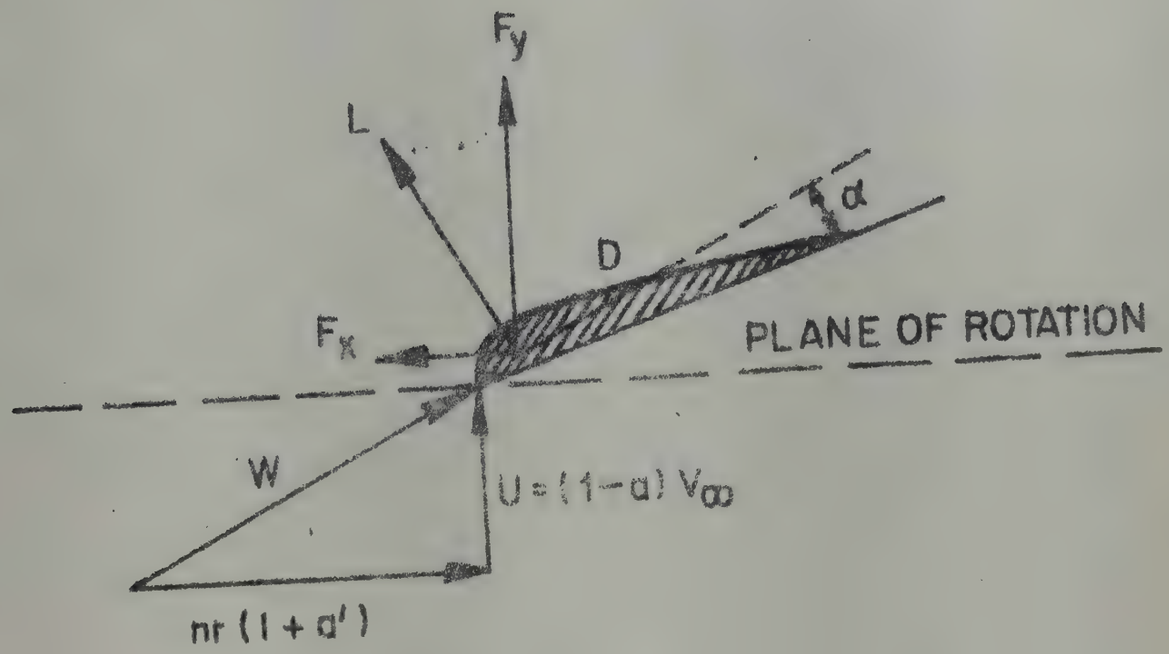


FIG. 11. VELOCITY AND FORCES ON A BLADE ELEMENT.

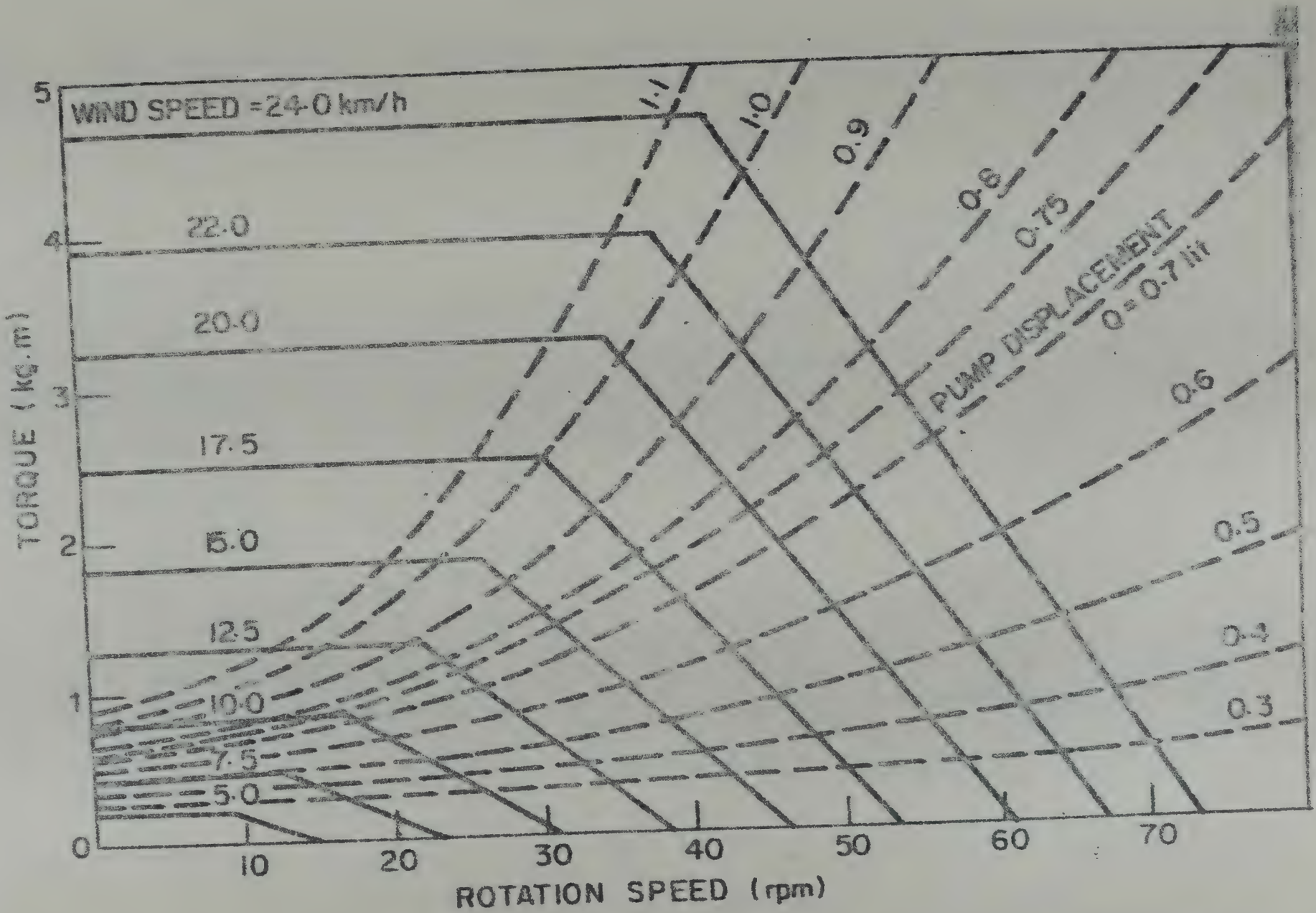


FIG. 12. TORQUE SPEED CURVES FOR WIND-MILL AND PUMP

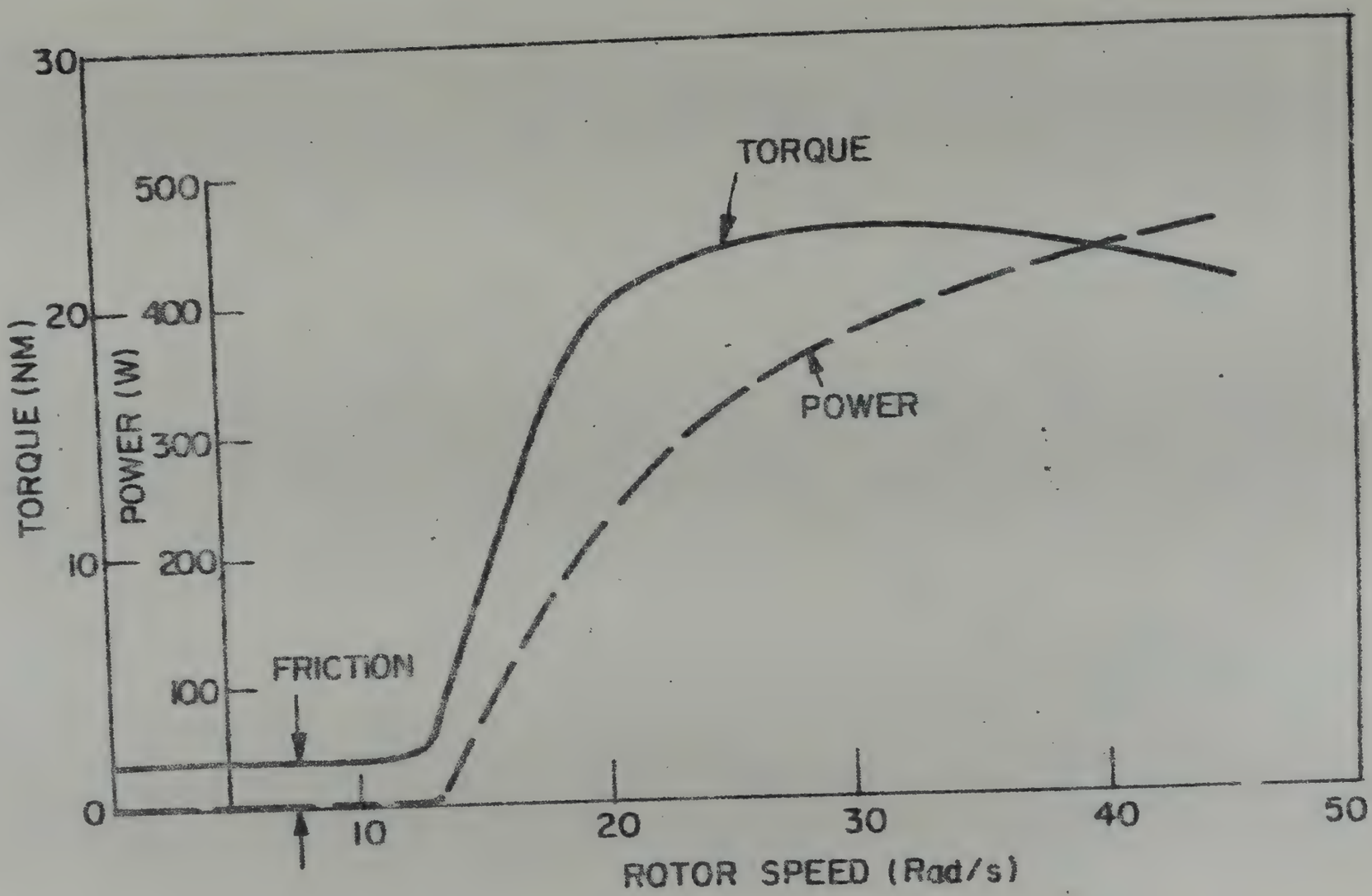
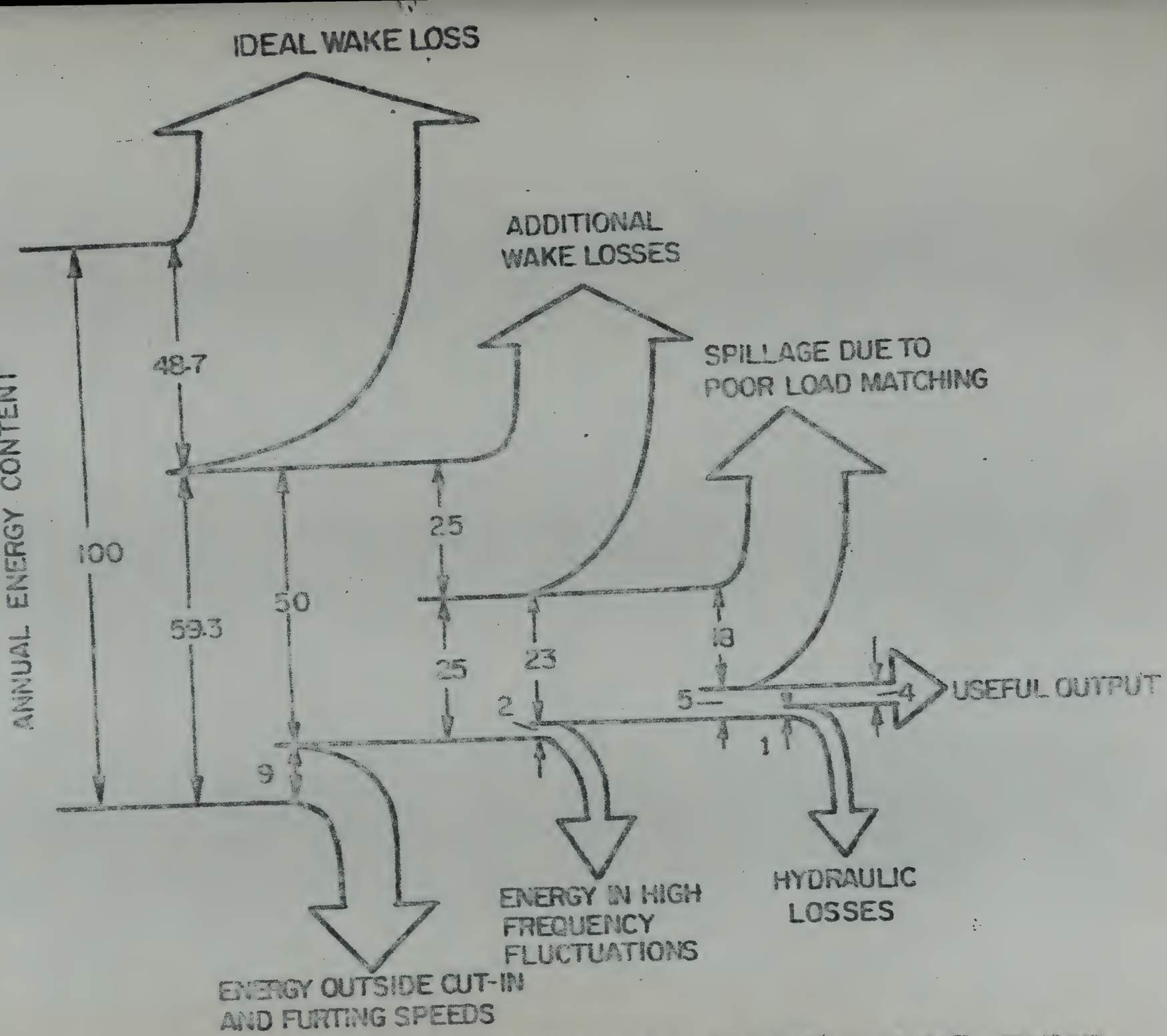


FIG. 13. CHARACTERISTICS OF AN ELECTRIC GENERATOR WITH REGULATOR AND BATTERY LOAD



FLOW DIAGRAM FOR A SIMPLE WIND-PUMP.

RURAL INDUSTRIALISATION: A CASE STUDY OF SISAL

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Lecture 4.1 (e)
Rural Technology
Course

RURAL INDUSTRIALISATION : A CASE STUDY OF SISAL

1. Introduction:

The purpose of social and economic organization is to fulfill the needs - physiological, psychological and philosophical - of the participants. That an average Indian village is not self-sufficient in production of goods and services needed, is beyond doubt. Recent studies have shown that traditional village ecosystems cannot even fulfill very basic needs of food and energy (Reddy, 1980). Due to existance of structural and social inequalities, even the low produce is not distributed properly.

Most of the developmental efforts towards improvement of village has been in land based activities. Oriented as they were towards the surplus producing farmer, these efforts never really improved the lot of bottom 30% of village population who are either landless or non-surplus yielding marginal farmers.

Hence it has now become necessary to focus upon non-land based economic activities. There are four options available: (1) Technologies to use local raw materials for products consumed locally (examples: Traditional industries like carpentry, pottery, modern consumption technologies like biogas, self-help housing); (2) Technologies to use local raw materials to produce exportable goods (examples: coir, handmade paper, food products, chemicals etc.); (3) Technologies

using bought out raw material for local consumption products (examples: metal forming industries, blacksmithy, handloom fabrics etc.); and (4) Technologies using bought out raw material for exportable goods (examples: handicrafts like ivory carving etc.).

Of these four options, the scope of (3) and (4) are quite limited for obvious reasons. Hence attention must be paid to technologies falling under categories (1) & (2). Since they are oriented towards use of resources of individual households (unless they are organised in a community fashion as is being done in Pura), it is quite doubtful whether technologies under option (1) can make a dent on the standard of living of resourceless persons who have only their labour to offer. Provision of employment then becomes vital, if these resourceless persons are to be helped. The following case illustrates how this can be done.

2. Criteria for choice of Technology: In searching for viable technologies under option (2), the following criteria are to be adopted:

(1) It is evident that the present employment pattern in a village is not uniform, but has seasonal fluctuations (see Fig. 2.1 for an example). The technology chosen should be able to adapt to this pattern. It should not have its own seasonal labour requirement that would conflict with present employment pattern.

(2) The technology chosen should not deprive any present activity with its resource. For instance, handmade paper from paddy straw would deprive cattle of fodder. If that happens then cost of substitutable material has to be included in evaluation.

(3) The technology chosen should lead to a tangible economic surplus. Otherwise external subsidy would be required which undermines self-reliance.

(4) The industry so selected should operate at such a scale that would maximise net gains to the region. The net gains would include surplus, wages and price paid for the material.

Keeping these in mind, the Karnataka State Council for Science and Technology launched a project to study the possible utilisation of sisal as a possible technology under option (2).

3. Sisal Industry in India: Sisal is one of the seventyfive varieties of Agave family. The spicie that is most common in Karnataka is Agave Veracruz. This plant was introduced by Portugese in this country. Sisal was planted along the rail tracks to prevent soil erosion and later introduced as a hodge plant. It was found that in 1800 A.D., villagers in Mysore State of then Madras province were using leaves of this plant to extract fibre and juice which was used as an anti white-ant agent in lime plaster (Watt, 1889). Experiments conducted by British officer

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showed that sisal ropes are more strong and durable compared to ropes that were being used by British Navy. It was decided to buy sisal ropes for British Navy.

Around 1850, the demand for sisal fibre (primarily to manufacture rope) had expanded in Europe and India exported Rs.25,000 worth of sisal fibre annually till 1875. Extraction of fibre was done using retting process in a decentralised way. Sisal was never promoted as a plantation crop in India, as major attention was directed to jute. But sisal was promoted as a plantation crop in Tanzania, Kenya and Brazil. When a machine, raspodar, was invented the price of sisal fibre from these plantations declined compared to fibre extracted through retting process. Besides raspodar extracted fibre was stronger compared to retted fibre. Indian farmers could not introduce raspodar as this was economical only if there were five acres under sisal. Sisal fibre industry died.

Several rope making companies had been established around 1920 in and around Calcutta to manufacture ropes from sisal, manil, hemps and jute. These organisations started importing sisal fibre from Tanzania, Kenya and Brazil. This continues till today.

After independence Khadi and Village Industries Commission was entrusted with the task of promoting village fibre industry. That KVIC has failed in its attempt is evident

from the fact that even today about 60-70% of sisal fibre is imported. Let us analyse the reasons for this non-achievement.

Fig.3.1 indicates that the demand for sisal rope is on the increase. The production has increased from 3300 tons in 1961 to about 9500 tons in 1979, the annual compounded growth rate being 5%. Sisal rope, being stronger than manila, hemp and other vegetable fibre ropes, is substituted only by nylon and other synthetic fibres. Hence price of sisal in the international market is influenced by price of synthetic fibre. Till OPEC price increase of petroleum products in 1973, synthetic fibre prices were low. Sisal fibre prices were also low and ruled around Rs.500-750 per ton (Fig.3.2). Since Indian sisal fibre from veracruz is considered to be inferior to imported sisalava fibre, the market price of indigeneous sisal price was lower than international price. At this low price, it was found that even by using raspodar, the average wage earned by a worker was only around Rs.500 per annum. (Anon, 1975). Because of such wage rates, the sisal fibre industry could not be promoted.

After the international price of sisal fibre started increasing at a rapid rate, there were attempts to procure the fibre locally. In fact, there were wide fluctuations in the quantity imported. (Fig.3.1). The import declined by an average annual value of 912 tons with a wide variation, (standard deviation 2301 tons) in the last 10 years. The

international price increased at the average annual rate of Rs.372/ton again with a wide variation (Standard deviation Rs.1772/ton). Because of these uncertainties the manufacturers were ready to buy Indian fibre. The raspodar based sisal fibre industry became profitable (average wage earnings Rs.15/day at full capacity utilisation).

This development posed another problem. Till 1970, there were only two captive plantations of sisal, owned by two rope companies (Jagannathan, 1979). Raspodars established at decentralized level were dependent on sisal plants on hedges. Procurement of leaves became a problem. And many of them operated at 50% capacity level. Sensing the opportunity, various forest departments started planting sisal on a plantation scale and leasing out to private contractors. Such plantations exist in Andhra, Orissa and plans are afoot in Karnataka. What could have been turned in to a rural employment scheme with little bit imaginative management was and is being handed over to middlemen and contractors.

This was the situation when KSCST formed its Working Group on sisal utilization.

4. Choice of products and Design of an industrial complex:

It is evident that production of fibre alone will not make a decentralised unit viable. Thevalue added in fibre extraction is Rs.3 per kg of fibre extraction while the value added in rope manufacture is Rs.9 per kg of fibre input. Then

if rural sisal industries are to be viable, they should go in for manufacture of rope. But small scale rope making machines, which would enable decentralized rope industry competitive with large scale organizations, are yet to be developed.

The yield of the fibre is only around 3-4% of leaf weight. The other possible products from the sisal plant are given in Fig.4. Whereas it is possible to harvest and utilize the leaves on a long-term basis at regular intervals, the roots, sap and stem can be used only once in the life span of the plant. Because of this, the Working Group, decided to concentrate on leaf and leaf products.

However, it was found that some of the leaf products mentioned are not suitable for manufacture in rural small industries due to reasons such as technological complexity and inoptimal operation at lower scale. After examining each product against these constraints the Working Group decided to concentrate on (a) rope from fibre, (b) hecogenin (used in the manufacture of steroids) from juice (c) wax from cuticle and (d) handmade paper from waste. Fig.4.2 gives a schematic of processes.

Laboratory trials indicated the following yields per unit weight of leaf: (a) fibre 4%, (b) Hecogenin 0.1% (c) wax 0.3% and (d) paper 2.5%. A survey for availability of raw material in the Ungra region was made. It was found out that about 4 tons per day of leaves would be available

within 10 kms of Ungra. An intensive market survey for these products were carried out (Gawande 1980). It was found that all products have a good demand and will help import substitution. Table 4.3 gives an account of the market position.

The criterion adopted to choose the scale of operation was, as mentioned earlier, maximisation of net present value of net gains to the region subject to cash surplus being greater than zero. The net present value per kilogram of leaves thruput, based on 10 years of operation are Rs.4.04, Rs.3.81, Rs.3.69 for scales of 2 tons per day, 3 tons per day and 4 tons per day respectively. Since the NPV is maximum for a 2 TPD plant, this scale was chosen for implementation.

A plant at this scale would produce

Rope = 16.5 tons/year	at a sales value of	Rs.3,30,000
Hecogenin = 0.5 tons/year	"	Rs.6,00,000
Wax = 2.25 tons/year	"	Rs. 67,500
Handmade paper = 15 tons/year	"	Rs.2,05,000

The capital cost would be Rs.6,42,000 which would earn a post tax internal rate of return of 30%.

5. Choice of organization: The choice of organisational form is an important consideration at the stage of implementation for a project of this nature, which is an attempt to develop an available resource for the benefit of the poor. In addition to transferring the economic benefits from the project to such a target group, the organizational form should also

facilitate the overall development of the people in terms of enhanced skills, attitudes, knowledge and autonomy. In this specific case it is proposed to form a Workers' Co-operative and all expenditure including interest on capital loan recovered from this co-operative from cash surpluses.

Based on the above findings a feasibility report (Anon 1981) has been prepared and implementation of a demonstration sisal complex would start soon.

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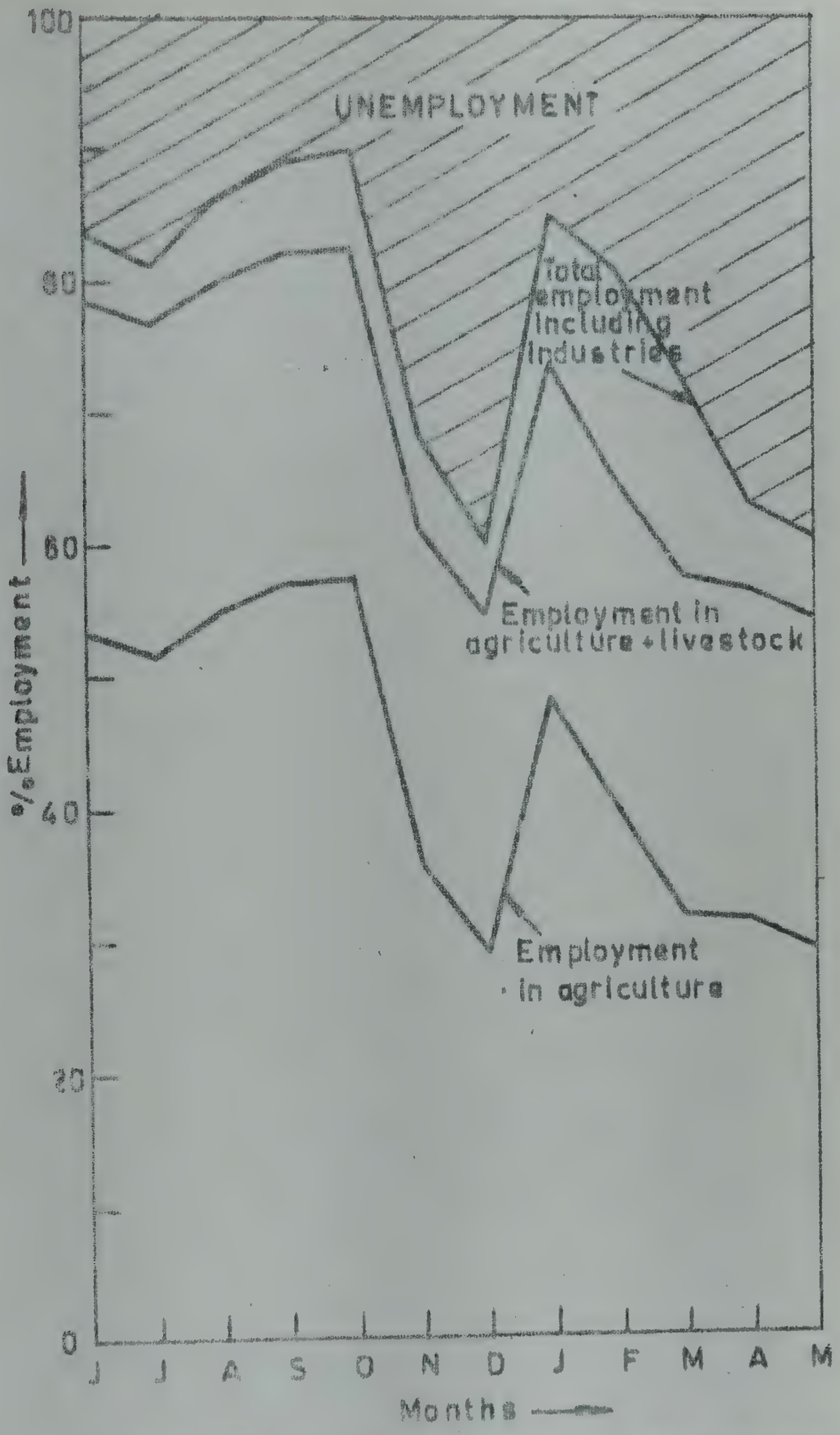

FIG. 2.1 - SEASONAL VARIATION IN EMPLOYMENT
(Source Venkatesha 1978)

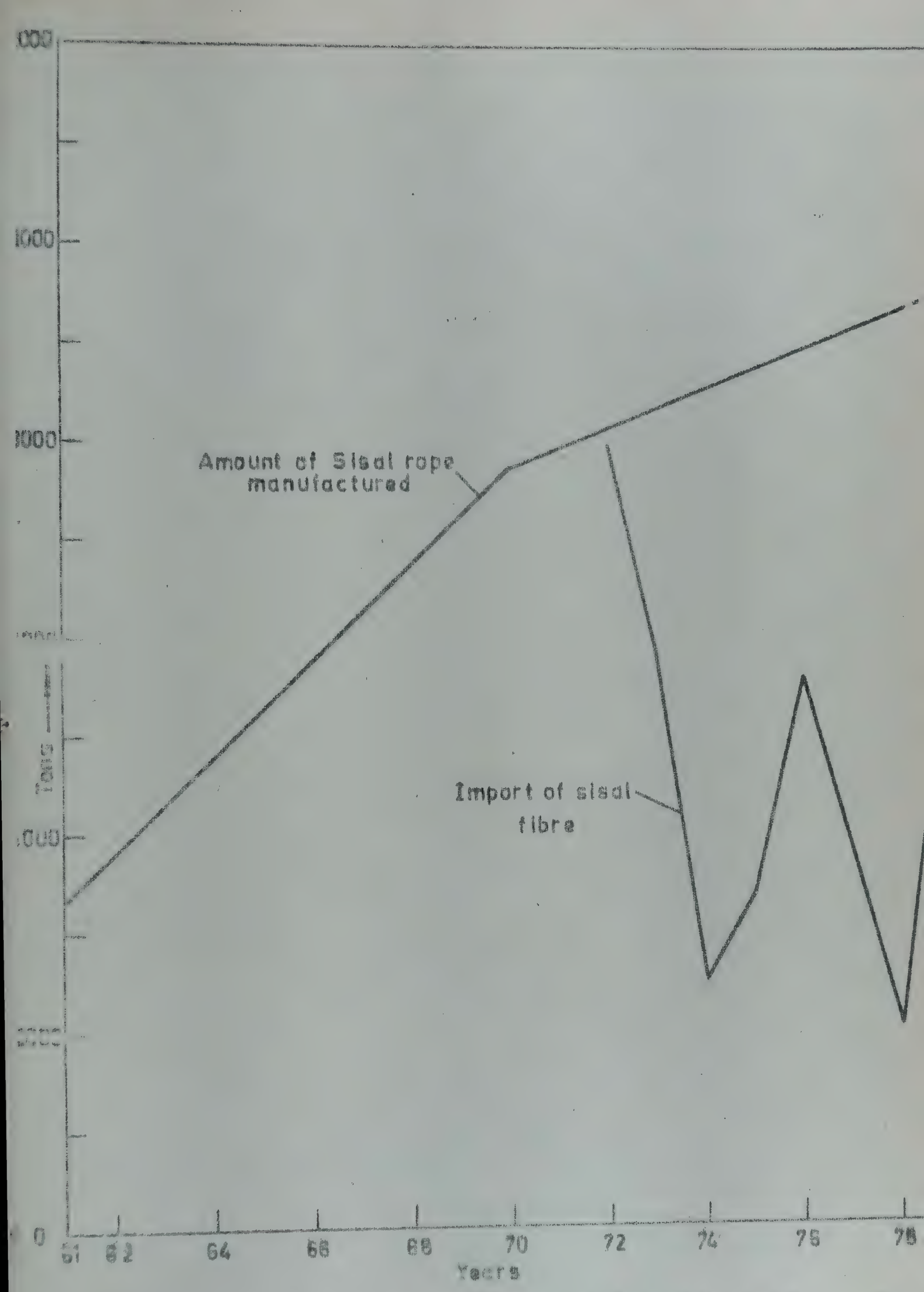

FIG:3.1 - (SOURCE Annual Survey of Industries and Monthly Statistics of Foreign Trade)

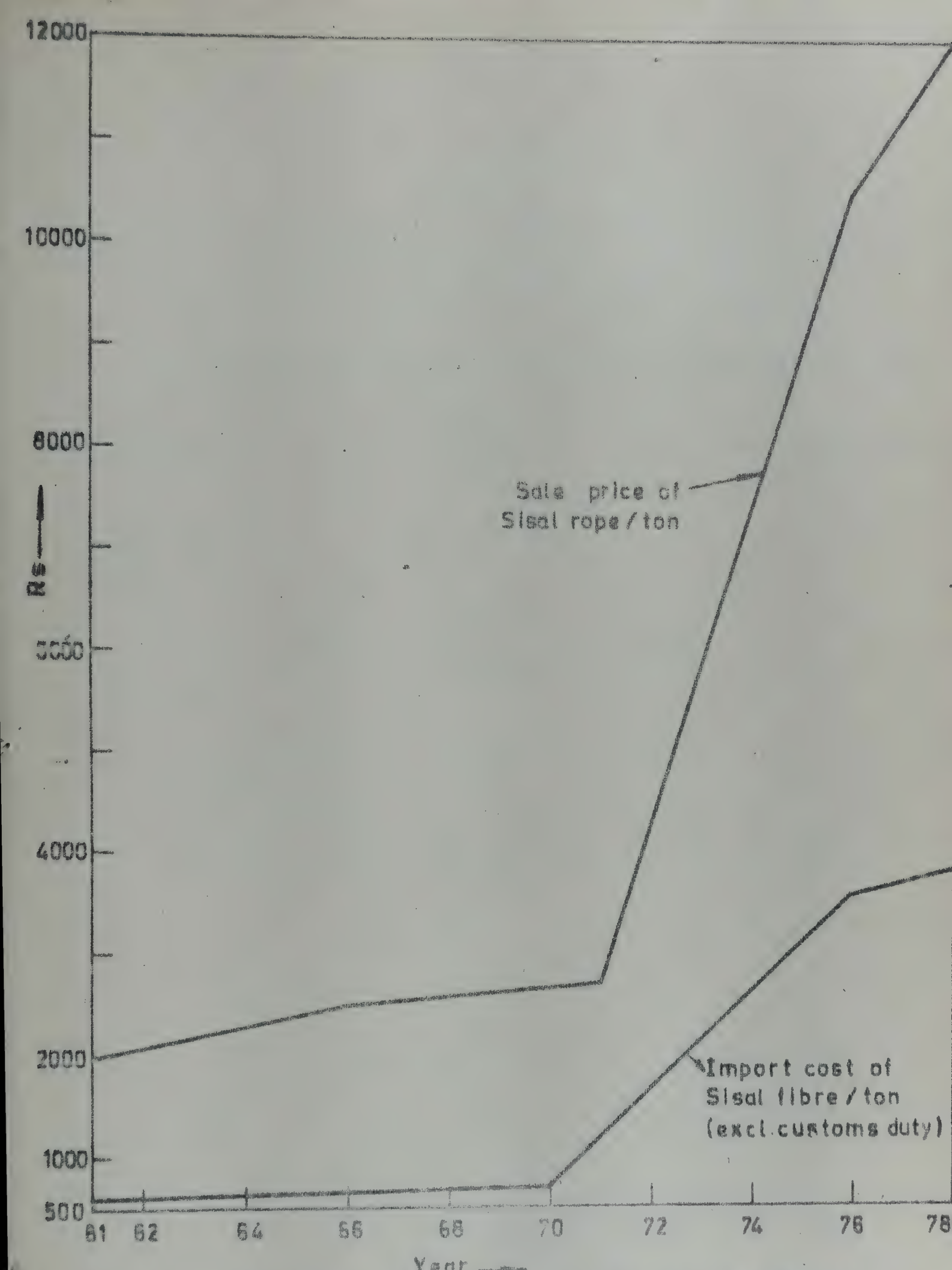

FIG. 3.2 - (SOURCE Annual Survey of Industries & Monthly Statistics of Foreign Trade)

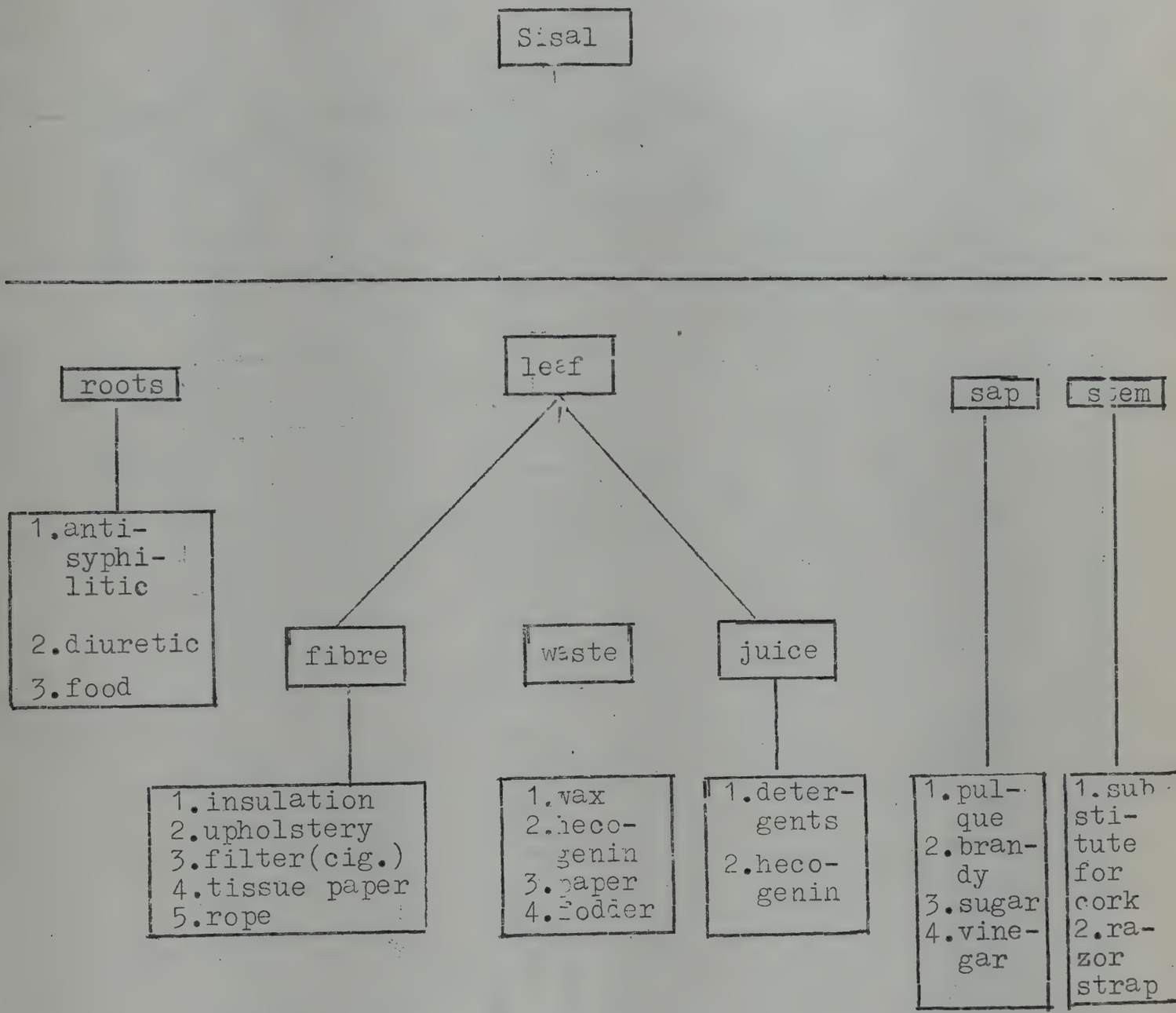
Sisal
roots
leaf
sap
stem
1.anti-syphilitic
2.diuretic
3.food
fibre
waste
juice
1.insulation
2.upholstery
3.filter(cig.)
4.tissue paper
5.rope
1.wax
2.heco-genin
3.paper
4.fodder
1.deter-gents
2.heco-genin
1.pul-que
2.bran-dy
3.sugar
4.vine-gar
1.sub sti-tute for cork
2.ra-zor strap

Fig. 4.1.

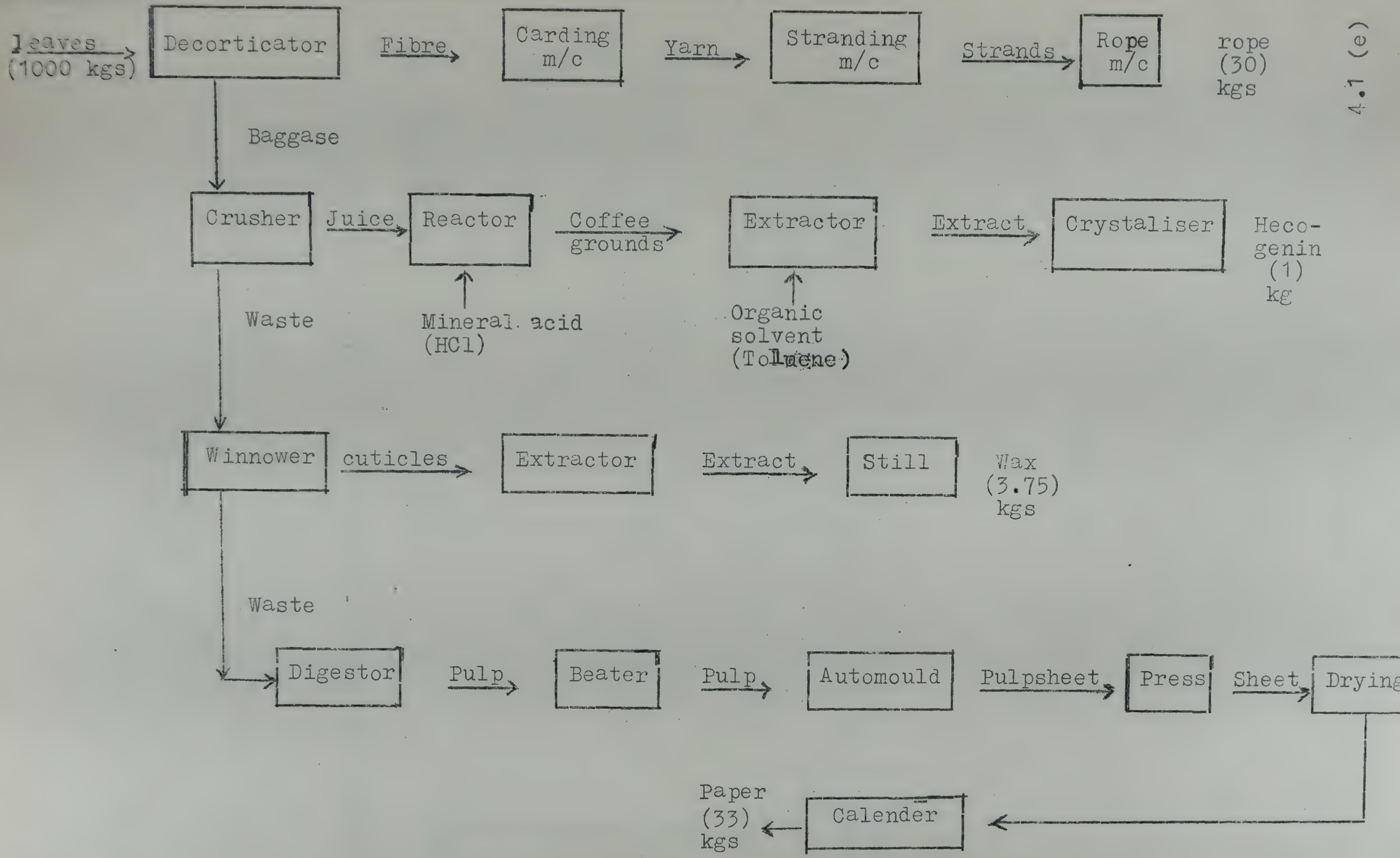

Fig. 4.2 Schematic of sisal complex

Table 4.3 : Demand Potential of Sisal Products

Product	Demand in 1979 (tons)	Sales price Rs./kg	Average growth rate(%)	Imports in 1979 (%)
Rope	20,000	26	5	80% of fibre to make rope is imported.
Wax	335	37	30	100
Hecogenin	20	1100		100
Handmade paper	30,000	28	5.6	10

SOILS AS POTENTIAL RURAL CONSTRUCTION MATERIAL

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Lecture 6.5
Rural Technology Course

SOILS AS POTENTIAL RURAL CONSTRUCTION MATERIAL

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INTRODUCTION

Materials technology in fact has met with the most challenging demands in the field of engineering design, be it a nuclear reactor to withstand exposure to radiation or materials for rockets. Yet when we look upon the availability of construction materials for low cost constructions direct choice is limited unless an ingenious way of exploitation of abundantly available material is examined.

Perhaps the greatest asset of all material sources is soil right under our feet. This forms the cheapest material if it can be used for construction purposes at the same location. Although many have learnt through trial and error methods as to how to make the best use of soil under different environmental conditions, a scientific approach would enable better to gainfully employ soil as building material. This was recognized as early as 1954 through the publication by Ministry of Information and Broadcasting (1954). BAKER (1976) clearly advocates a case for such scientific approach particularly for rural applications.

SOILS AS ENGINEERING MATERIALS

Soils in general are multicomponent, multiphase particulate systems with very poor bonding. Coarse grained constituents of soils due to low surface areas does not permit the soil systems to form cohesive bonds if the soils are converted to soil systems under external effort such as compaction. Induced cementation bonds either by burning or chemical addities might be needed to provide needed performance under different environmental conditions. This is normally done by different methods of soil stabilization. Soil is one of mankinds oldest building materials and traditional methods of soil construction such as rammed earth,wattle and daub and abode are still commonly used in many regions of the world.

SOIL BLOCKS FOR BUILDING

Ever since man crossed the stone age the art of pot making as well as brick making have paved the way for the advancement of cultural heritage. The techniques in this industry are as old as those in agriculture. One may wonder what new information could be added to age old brick industry since a feeling of satisfaction prevails among traditional brick moulders and modern brick factories. Although soil may be adequately strong for building construction it is not very durable, has little resistance to moisture. The effects of its poor weathering performance can be seen in many developing countries where rural houses must be maintained regularly or even completely rebuilt at intervals, especially in areas

with moderate rain fall. In spite of abundant information being presently available regarding bricks the following aspects merit closer examination:

(i) role of soil constituents on performance of soil blocks

(ii) methods of block making (This would be discussed separately)

(iii) influence of wetting and drying cycles on strength and durability

(iv) rain simulation tests in assessment of performance of soil blocks.

ROLE OF SOIL CONSTITUENTS ON WETTING AND DRYING

Soils are essentially disintegrated rock weathered materials existing in graded fractions. Generally speaking soils containing less than 20 per cent clay are classed as gravel and sand, loamy sands, sandy loams and loams, soils containing 20 to 30 per cent clay are called clay loams while those containing over 30 per cent clay are called as clays (LUNT 1980). This classification is arbitrary. On the other hand clay fractions alone due to their large surface area can be regarded as the main soil constituent that control the degree of possible densification in making soil blocks and the consequent strength and resistance to erosion, the extent of moisture absorbtion that in a way reflect soils instability when wet. The presence of sand and silt fractions

can be regarded as inclusions that dilute the surface actively and the associated phenomena. The presence of soil with the optimal soil constituents or possibility of judicious combination of soils of borrow area forms a prerequisite for production of satisfactory blocks. Hence one of the most important aspects is the selection of soils for bricks. This is in one sense is done by particle size analysis. It is possible to separate the soil down to and including fine sand by simple method of sieveing. The silt and clay fractions cannot however be determined by this method but only by using lengthy and intricate hydrometer methods based on sedimentation. To overcome this difficulty the plasticity index has been taken as the basis (Ramaswamy and Vaidyanathan 1979) for brick earth blend. The investigation mainly pertained to the burnt brick. Maximum compressive strength is obtained at optimum values of around 45% fines content and around 18% of plasticity index, irrespective of the source of the brick earth and mode of burning. Corresponding information for processing of soil for unburnt with or without stabilizers has not been generated to the extent that permits generalization.

The laboratory testing programme consisted of (soil) fractionised soil batches with different liquid limits (red earth 31 to 39 per cent, black cotton soil 74 to 94 per cent) for making blocks. Since the percentage of constituents are different its potential for interaction with water

is different and in turn the compaction characteristics. Table 1 and figures 1 and 2 show the variation of compaction characteristics as the concentration of fines increase. At the corresponding maximum density and optimum moisture contents samples were compacted to determine their strengths. It can be seen in Table 1 that the strength is very sensitive to the densities realized and corresponding water contents. In practice compacted soil blocks while used for wall construction, if moisture absorbtion is not prevented, naturally degree of saturation increases and strength falls down markedly. To simulate this condition samples were exposed to 95-98% relative humidity environment. Dependent upon the initial degree of saturation samples reached corresponding high degrees of saturation upto 98%. Table 2 shows the drop in strength that takes place due to this wetting cycle. Although this value of strength is low, it is likely that in actual practice the loading intensities are well within this limit thereby providing adequate factor of safety. It is not practicable that samples get completely saturated an situation that would arise in an unforessen event of flooding and submergence. As such the soil blocks would possess necessary reverse strength even in the event of moisture absorbtion due to exposure to rain.

The other aspect that has been examined is regarding the strength of blocks subjected to repeating wetting and drying as happens in actual field conditions due to changes in

weather conditions. As a part of basic investigation it has been studied (Allam and Sridharan 1981) as to what happens to the shear strength of soil when subjected to repeated exposures to different degrees of relative humidity. It has been noticed that strength increases as the number of cycles increases. Figs. 3 and 4 shows the results of the present investigation about the levels of equilibrium realized as the number of cycles increases. It can be seen that with each cycle the extent of absorbtion of moisture decreases. This in turn is reflected by slight reduction of measured water contents (Table 2). This is attributed to possible reduced surface activity due to formation of descication bonds. Strength data shows that there is considerable increase in wet strength which is at least in the range of 35-40 percent for the number of cycles only in the range of ten. Investigations are under progress to find out whether this strength increase is due to either associated changes in void ratio or cementation effects. It has also not been possible due to this limited investigation to clearly identify as to how the relative proportions of solid constituents influence the strength response due to wetting and drying. The general indications are that as the concentration of fine grained soils increases the relative increases in strength are more. While black cotton soils examined for their response under wetting and drying cycles, it was observed that the samples disintegrated rendering the material unsuitable for blocks inspite of its high as compacted and air dried strength. Tests are

under progress to determine as to how to reduce this physico-chemical activity of soil so as to be compatible with the changes induced due to different environmental conditions.

RAIN SIMULATION TESTS - STATE OF-THE-ART AND REQUIREMENTS

In some of the attempts made towards the rain simulation test, reference can be made to environmental tests for electronic equipment. The object here has been mainly to determine the suitability of equipment to be free from water seepage. The standardized form of test (IS 2106- part XI 1965) is to develop a spray under a static pressure of 3.2 kg/cm^2 ±12% from eight shower heads. This discharge end of each nozzle shall consist of a flat nonrustable metal plate of 2 mm thickness having 36 holes each having a diameter of 1 mm spread on concentric circles of outermost diameter of 5 cm dia circle (16 holes) and reduces to 4, 2.5 and 1.25 cms with 8, 8 and 4 holes respectively. The spray from 4 of the shower heads shall be directed downwards at an angle of 45° at each of the uppermost corners of the equipment under test. Spray from the remaining 4 heads shall be directed horizontally at the centre of the area of each of the four sides. The shower heads shall be located at a distance of 50-75 cms from the corners or the sides of the equipment under test. At the end of the test the equipment shall be removed from the chamber and subjected to a performance check.

The specific requirement of the above test facility is to simulate mainly the intensity of rain fall. The problem of

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erosion does not arise and the test mainly examines whether water enters the system under different intensities of rain thereby impeeding the performance. Although the general principle of test facility are tenable still it merits further examination with regard to specific requirements of testing of mud blocks.

In the case of mud blocks used in construction, the available strength is far too high of the requirement if it can be preserved during the performance. When soil block are used in wall construction and exposed to rain two things happen in the case of unprotected block walls: (i) the exposed face absorbs moisture thereby increasing the degree of saturation and the moisture , moves towards the unexposed interior face. In certain cases when the top of the wall is not protected moisture absorbtion might start from top and move downwards. (ii) Due to the impact of the rain different degrees of surface pitting and erosion might take place. This could assume serious proportions if the surface/bonding forces operative in soil systems are low.

Some of the earlier methods and recent methods attempted to develop appropriate methods of rain simulation are cited below. Presently the recognised method of performance test is according to IS code 1725-1960. Samples need be soaked for 24 hours and then rubbed with a wire brush and weighed. This cycle is repeated 12 times and the weight loss is expressed as a percentage of initial weight. A permissible limt of 10 percent

is stipulated. The test neither simulates the moisture migration from exposed face nor the impact of rain drops and associated erosion. In the case of mud blocks which are poorly bonded materials, this test is too severe and unrealistic and would result in disqualifying the material which would otherwise be suitable. Subsequent attempts are in a way moves towards the more realistic situation. Vidyanathan and Ramaswamy (1978) in their investigation on strength and erosion resistance of rammed earth walls describes their rain rebound rig. This consists of a constant head tank with an outlet pipe at the base feeding to a horizontal pipe with uniformly spaced orifices. These orifices ejects jets of water on a sloping deflector which broke the jets into droplets of 1 to 2 mm diameter of almost constant spacing and velocity. A two minute discharge from this may be considered equivalent to a rainfall of 1.3 cm. Although this method in principle is intended to simulate rain fall none of the parameters needed for simulation have been measured which are needed for subsequent control of the same. Further the equipment is not small enough for transportation to field.

The spray test suggested by Department of Housing and Urban Development (HAND BOOK FOR BUILDING HOMES OF EARTH) is another attempt in this direction. A spray nozzle that can produce a hard spray all over the block is used. The shower has a diameter of 4" and pressure head employed is 20psi. Spray nozzles are placed exactly 7 inches away from the faces

of the block. After two hours of spraying remove blocks and examine them closely. The depth of pitting or surface erosion is determined. The simulation is more realistic and the facility is handy. Details are not available as what these dimensions mean and what numerical parameters they simulate. In order to examine in depth the methods of simulation and as well as to look for an alternative method the following aspects merit consideration.

PARAMETERS INVOLVED IN RAIN SIMULATION

Inside all clouds the processes of condensation and aggregation produce particles of larger size. Rain consists of larger drops having radii upto 2 mm. The heaviest rain is composed of even larger drops that fall from clouds whose depth may reach 10 kms. Typical data according to MASON (1975) radius of drop is 1000 microns. v = terminal velocity as 6.5 m/sec. and n, number per litre is unity. According to the size ranges furnished by particle measuring systems the particle diameter size ranges from 4 microns for fog to 15000 as upper limit for hail. Rain drops range in size from 400 to 8000 microns (0.4 to 8 mm). Intensity of rainfall need be assumed to decide upon the exposure time. To determine the concentration of drops impact on unit area particle number density need be computed.

The following rainfall data is suggested for the design

clear hole which are related to their sizes.

Suggested approaches:

The possibility of using fulljet nozzles or similar types developed for other industrial purposes as a method of rain simulation merits examination. This would become feasible and handy provided all the parameters in rain simulation discussed earlier, can be realized. Another approach is to examine what order of spray velocities can be obtained when handpumps are used. If it is possible to obtain a terminal velocity of 6.5 m/sec. then a suitable perforated disc can be introduced into the system. It might be possible to get the needed velocity but the discharge could be very high. Then a suitable cut off could be introduced. The particle size distribution and concentration need be determined employing the method suggested earlier.

CONCLUDING REMARKS

It is for us to make soil acceptable and live with it employing suitable methods to achieve desirable properties and performance. It is open to us to take up all the challenges to surpass the difficulties or consider ourselves to be over such things as 'MUD'.

of rain simulation rig.

1. Rain drop diameter at impact

2 mm	-	Medium Intensity
4 mm	-	High intensity

2. Maximum terminal velocity of impact :6.5 m/sec.

3. Maximum intensity of rain fall - 15 mm/hr

4. Collecting area at the month of rain gauge 50 cm^2

5. Collecting area at the bottom of rain gauge - 200 cm^2

The following details are provided for purposes of determination of particle diameter.

Fletcher (1966) provide a detailed report of the experimental techniques for this purpose. The most obvious method of examining the droplet population is to catch all the drops over a given area and examine them with a magnifying lens or a microscope. Most methods for determining droplet concentration and size distribution do essentially just this and vary only in the means by which they attempt to overcome the difficulties involved.

Of the methods available the replica method developed by MAZUR (1943) can be adopted easily. In this method rather than the droplets themselves the slide covered with a thin film of magnesium oxide powder obtained by burning a magnesium ribbon near the slide. The film is soft and droplets leave

PARTICLE MEASURING SYSTEMS INC. - Size ranges of standard PMS particle size spectrometers

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TABLE 1

(a) Red Earth G = 2.68

Passing through B.S. Sieve	Liquid limit	Plastic limit	Shrinkage limit	Proctors Compaction r_d lb/cft.	O.M.C.	Sr.	Strength as compacted
7	31	14.8	12	118	15.5%	99.6	105.89 lb/in^2
36	33	12.4	15	110	16.5%	85.0	57.85 lb/in^2
72	39	20	20	108	19%	92.9	154.43 lb/in^2

(b) Block Cotton Soil G = 2.75

Passing through B.S. Sieve	Liquid limit	Plastic limit	Shrinkage limit	Proctors Compaction r_d lb/cft	O.M.C.	Sr.	Strength as compacted
7	74	37	5.0	88.5	32%	93.6	69.86 lb/in^2
36	82	43	11.7	87	29%	81.38	-
72	94	45	11.8	-	-	-	-

Table - 2

Unconfined strength after wetting and drying cycles

Sl. No.	Sample Details	Weight of sample at equilibrium (gms)	Water content after the test (%)	Unconfined compressive strength (PSi)	Ratio of strength to that after 1 cycle	Remarks
1.	Red Earth (passing BS 7)	194.20	18.79	9.65		At the
		193.86	18.73	9.80		end of
		194.26	18.74	11.00		1 cycle
				Av 10.15	1.00	
		191.31	17.12	18.00		At the end
		192.03	17.37	16.50		of 5 cycles
				Av 17.25	1.70	
		191.14	17.00	17.00		At the end of
		191.00	16.90	19.20		10 cycles
		191.35	17.18	16.50		
				Av 17.60	1.75	
2.	Red Earth (passing BS 36)	186.56	21.26	13.60		At the
		186.77	21.14	13.20		end of
		185.38	20.59	13.90		1 cycle
				Av 13.60	1.00	
		183.95	19.45	17.30		At the
		182.43	19.50	18.70		end of
				AV 18.00	1.32	5 cycles
		182.48	19.50	19.60		At the
		182.65	19.79	19.00		end of
		182.56	19.57	19.00		10 cycles
				Av 19.20	1.42	

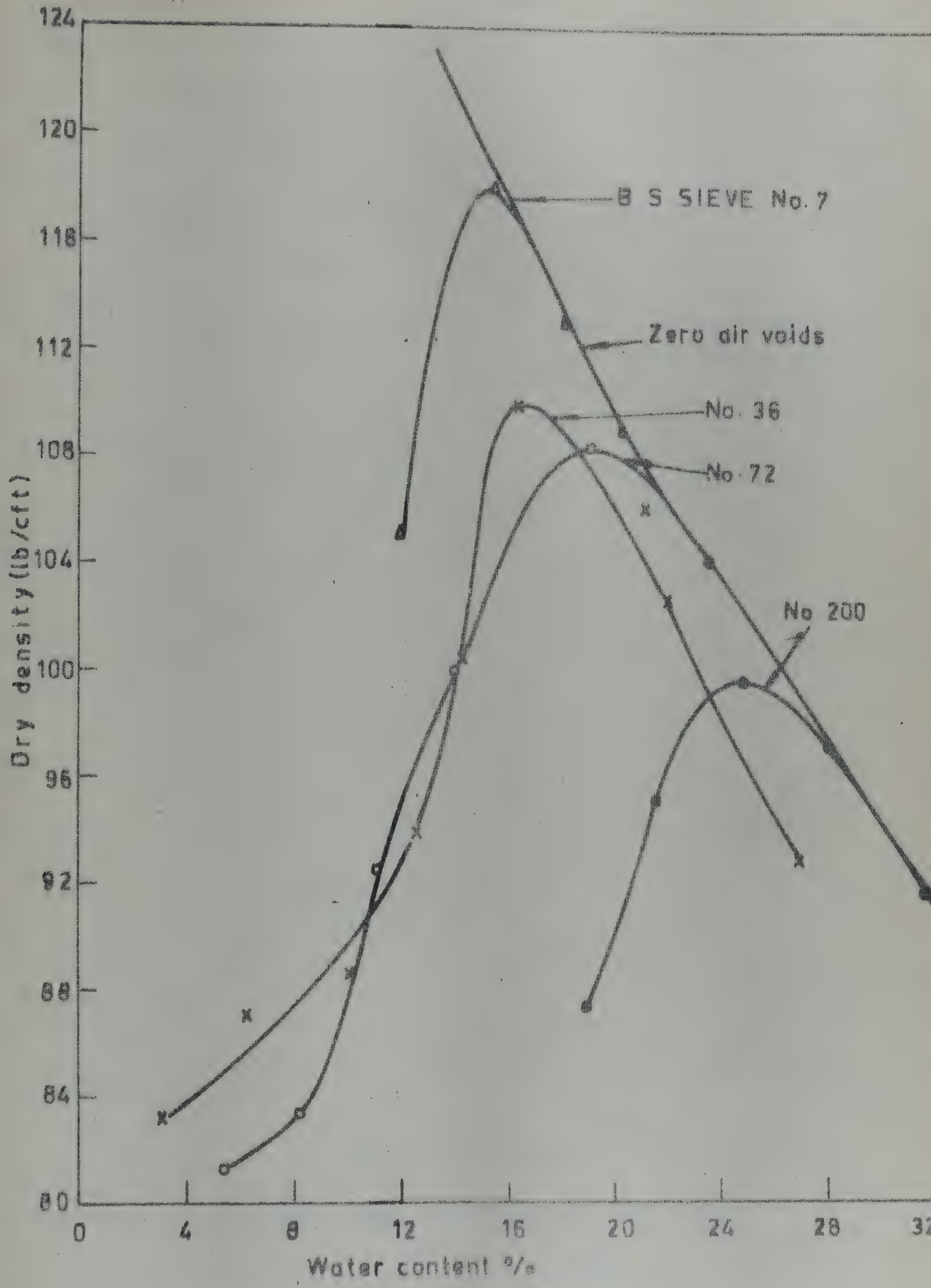

FIG. 1 - PROCTORS COMPACTION CURVES
(RED EARTH)

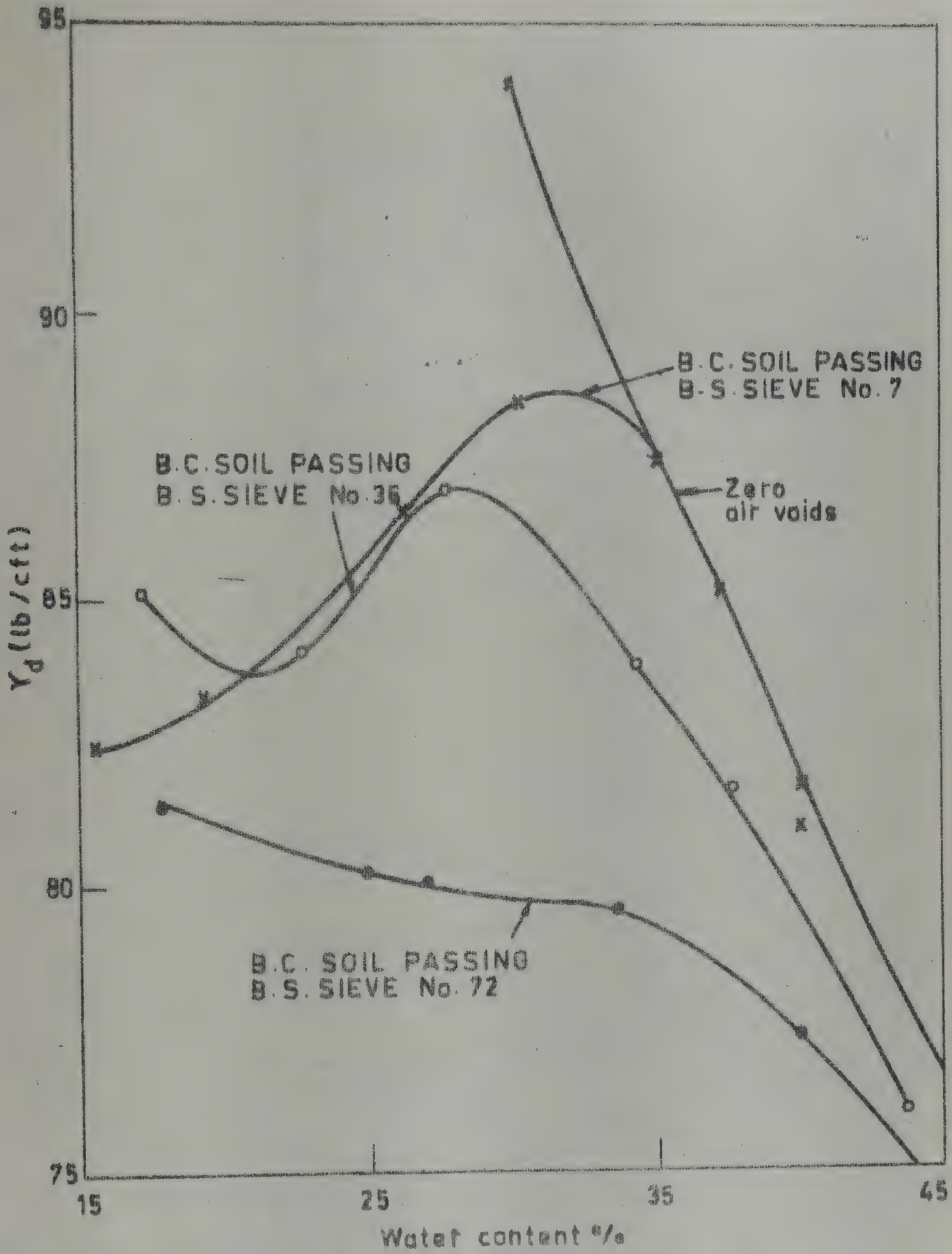

FIG. 2 - PROCTORS COMPACTION CURVES

(BLACK COTTON SOIL)

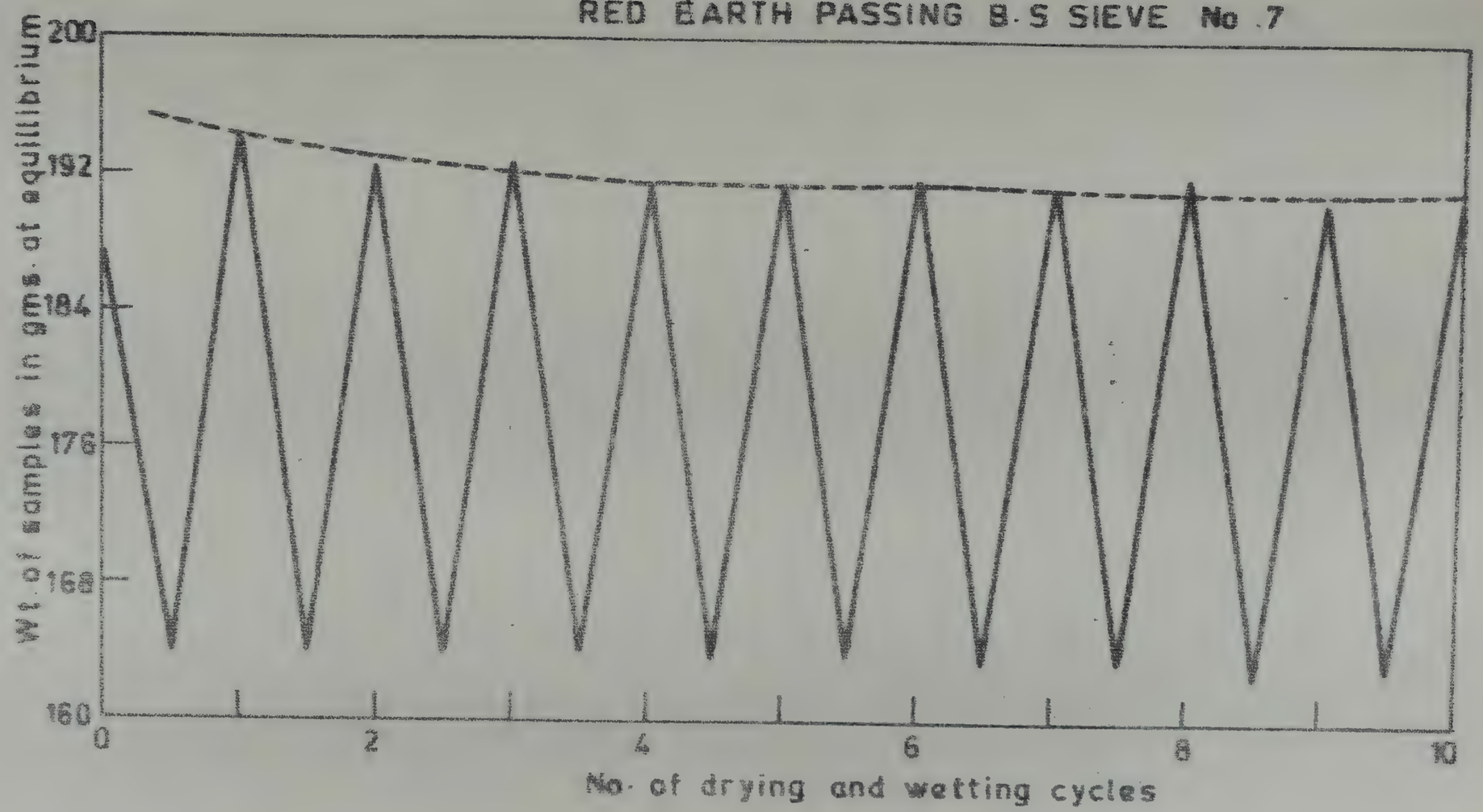

FIG. 3 - EQUILIBRIUM STATES UPON WETTING AND DRYING

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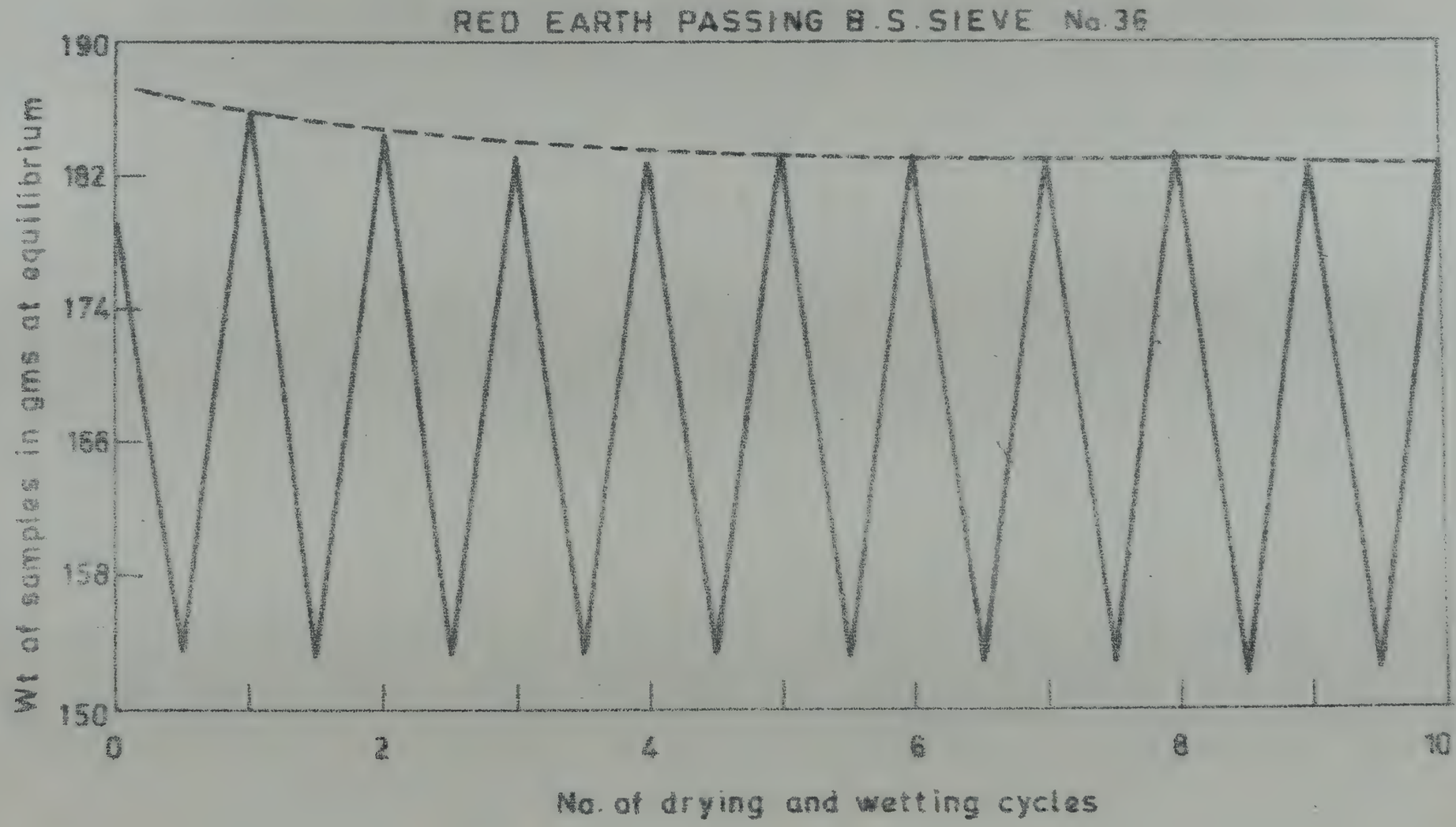

FIG. 4 - EQUILIBRIUM STATES UPON WETTING AND DRYING

SOIL STABILISATION

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Lecture 6.6

Rural Technology Course

SOIL STABILISATION

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Introduction

Soil is one of the oldest building materials and many traditional methods such as rammed earth are commonly used in many regions of the world. Although soil may be adequately strong for building construction, it is not very durable and has little resistance to moisture. Its poor weathering performance requires frequent maintanance or complete rebuilding.

Methods to improve the natural durability and strength of the soil - commonly referred to as Soil Stabilisation - have been practised in many countries. Stabilisers such as natural oils, plant juices, animal dung and crushed ant-hills, have been used for many centuries. In recent years scientific rather than adhoc techniques of soil stabilisation have also been introduced, developed largely by highway engineers. In this note brief discussion on soil and its classification, clay minerals, principal soil tests, lime, cement and other stabilising agents, strength of stabilised blocks has been carried out.

Soil and its classification

Soil consists of disintegrated rock, decomposed organic matter and soluable mineral salts. Under the engineering system of classification which is widely accepted in earth construction a soil is graded into fractions according to size of particles, as follows.

> 300	mm	- Boulders
8-300	mm	- Cobble
20-80	mm	- Coarse gravel
4.75-20	mm	- Fine gravel
2-4.75	mm	- Coarse sand
0.425-2	mm	- Medium sand
0.075-0.425	mm	- Fine sand
0.002-0.075	mm	- Silt
< 0.002	mm	- Clays

It is the clay fraction which is major importance in earth construction since it binds the larger particles together thus enabling a soil to be used as a building material. Unfortunately clay readily absorbs moisture, and this is the main cause of soil's instability when wet.

Clay Minerals

The term Clay refers to that size fraction of soils with particles of less than 0.002mm effective diameter as measured from their setting velocity in water. It also

refers to certain minerals, called clay minerals, which are the result of chemical weathering of rocks and which are usually not present as larger particles.

The clay-size fractions of most soils contain clay minerals. However, there are soils in which clay-size particles are either non-crystalline, amorphons materials or primary minerals such as quartz, feldspar etc. They do not have the property of high plasticity associated with clay minerals.

Clay minerals are alumino-silicates, ie. oxides of aluminimum and silicon with smaller amounts of metal ions substituted within the crystal. The aluminium-oxygen and silicon oxygen combinations are the basic structural units which are bonded together in such away that sheets of each one result. They are called silica sheet and alumina sheet. The stacking of these sheets into layers, the bonding between layers and the substitution of other ions for aluminium and silicon account vfor the the different numerons minerals.

The clay minerals are classified on the basis of the component layers. Most of the clay minerals could be grouped into any one of the following groups viz., Kaolinite, Illite and Montmorillonite groups.

(i) Kaolinite: The Kaolinite crystal is made of repeating layers, each layer consisting of a silica sheet and an alumina sheet sharing a layer of oxygen atoms between them.

The layers are held together by the hydrogen bonding between hydroxyls from the alumina sheet on one face and oxygen from the silica sheet on the opposite face of the layer. A typical kaolinite particle may be 70 to 100 layers thick i.e. about 700Å thick. Kaolinite have low liquid limit, in the range of 50% and low specific surface about $10m^2/gm$. Other clay minerals which could be grouped into this group are Halloysite and Dickite.

(ii) Illite: This is also called as clay Mica. They have repeating layers consisting of an alumina sheet between two silica sheet with oxygen shared to give a unit four oxygen atom thick. The layer is 10Å thick. The layers are bonded together by potassium ions which are just the right size to fit into the hexogonal holes of the silica sheet. The clay minerals in this group are illite and glanconite, They have liquid limits in the range of 80% and the surface area about $80m^2/gm$. Illite occurs widely in sedimentary rocks in temperate and in arid regions.

(iii) Montmorillonite: The montmorillonite minerals have the same layers as the clay micas(Illite). However, the potassium binding does not exist. Substitutions occurs in alumina sheet, with magnesium or iron substituting for aluminium. The different montmorillonite minerals have different substitutions. The montmorillonite clays have high activity and high liquid limits(300-800%). The surface area ranges 600-800m2/gm. The most obvious charac-

teristic is the swelling of the clay to several times its dry volume when placed in contact with water. This swelling is due to water adsorbed between layers pushing the layers apart. When layers become separated by several thicknesses of water molecules, they can be considered to act as individual particles. Montmorillonites occur in sediments of semi arid regions and are the main minerals in bentonite rock.

Soil Tests

(i) Particle Size Analysis:

It is the particle size distribution or grading of a soil which determines how effectively it can be compacted and stabilised. A well graded soil will therefore contain the correct proportions of different sizes particles, with all voids between larger particles being filled by smaller ones.

In order to determine the composition of a soil, it is necessary to separate and determine the proportions of the different sized particles, fine gravel, coarse sand, fine sand, silt and clay. It is possible to separate the soil down to and including fine sand by the simpe method of sieving. The silt and clay fractions cannot however be determined by this method but only by using lengthy and intricate tests of hydrometry and sedimentation. Field tests have been devised to separate the fines from the rest of the soil. These involve shaking the soil in water and either decanting

off the finer material which is in suspension, or allowing the soil to settle into different layers. For all important soil building projects, a full laboratory analysis should be carried out on the soil using appropriate tests.

(ii) Atterburg Limits:

Clays vary greatly in their physical and chemical characteristics, and because of the extremely fine size of the particles it is very difficult to investigate their properties. For the purpose of soil stabilisation the plastic properties of a clay can be conveniently expressed in terms of plasticity using standard tests. They are liquid limit and plastic limit tests. As the water content is reduced a point will be reached when the system no longer behaves like a liquid and below which it possesses shear resistance. This point is called the liquid limit and is usually defined as the moisture content at which the soil passes from the plastic to the liquid state when determined in accordance with a standard test procedure.

When further drying, the clay system will increase in density and it then behaves like a plastic paste, so that it is continuously deformed when a force is applied to it but retains its new shape when the force is removed. Reducing the moisture content still further eventually causes the clay to crumble under load and to deform plastically. At this point the clay isat its plastic limit . The plastic

limit is defined as the moisture content at which when it is threaded crumbles, the thread diameter nearly equal to 1/8". The numerical difference between the liquid limit and the plastic limit of a soil is the plasticity index.

A high liquid limit and plasticity index indicates that a soil has a great affinity for water and will therefore be more suceptable to moisture movement.

Different values for liquid limit and plasticity index have been proposed by different workers for soils to be suitable for stabilisation. Maximum values of 50 for liquid limit and 30 for plasticity index have been suggested.

(iii) Organic matter and soluable Salts:

The surface layer of the soil usually contains organic material in the form of humus which may seriously impair the setting or hardening of cement or affect the pozzolanic reaction between lime and the soil. In most cases removing the top soil and using only the soil beneath will ensure that no organic matter is present. However in some regions, particularly near rivers, organic matter can be found to a considerable depth. In these localities, it is desirable to test the soil to determine whether or not organic impurities are present. One test consists of determining the pH of a soil-cement mixture. The pH is measured one hour after mixing in water, and if it is below 12.1, the soil is considered to be unsuitable for stabilisation with 10% or less of cement since it shows that cement hydration has been affected by

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the organic impurities. The test is simple to perform.

In some areas(for example arid and semi-arid regions) the presence of soluable inorganic salts particularly sulphates, may make the soil unsuitable for stabilisation with either cement or lime. This is because any increase in moisture content can lead to chemical reactions which result in expansion and disruption of the soil. Such reaction can occur both between the sulphate and the cement and between the sulphate and the clay fraction of the soil. The latter reaction occurs at high pH values such as when lime is added to sulphate bearing soils. Sulphate content between 0.5 and 1.0% are said to represent the upper limit for successful stabilisation. The actual value however will depend on the type of sulphate and the amount of clay present in the soil. In areas which are known to contain sulphate-bearing soils, it is therefore important to analyse soil samples in order to determine the amount of sulphate present. If this is greater 1.0%, the soil is unlikely to be suitable for stabilisation and should not be used.

(iv) Moisture-Density relationship

Compaction is measured quantitatiously in terms of the dry density of the soil, which is the weight of the soil solids per cubic feet of the soil in bulk.

The increase in the dry density of soil produced by compaction depends mainly on the moisture content of the soil and on the amount of compaction applied. With a given amount of compaction there exists for each soil shown in Figure 1, a moisture content termed as the Optimum moisture content (OMC) at which a maximum dry density is obtained. As the compaction effort increases, the maximum dry density (MDD) increases and the optimum moisture content decreases. The values of OMC and MDD depends upon the soil type and the compactive effort and the choice of stabiliser. Standard laboratory compaction tests are listed, they are viz. Proctor's test and the modified AASHO Test. The moisture density relationship should therefore be determined using the particular soil/stabiliser combination and the method and degree of compaction which will be used in practice. The OMC found will therefore be the same as that to be used on site and the corresponding density can be a useful quality control against which production blocks may be compared.

Principles of Soil Stabilisation:

Because of the clay binder, unstabilised soil will swell on taking up water and shrink on drying. Further the strength of the soil will be less. The aim of a soil stabiliser is therefore to increase the soil's resistance to the destructive properties of the weather and to increase the strength of the soil. Some of the common stabilisers are cement, lime, bitumen and other additives.

(i) Cement: Table-1 gives some information on cement stabilised soil. There is usually an approximately linear relation between cement content and strength. (Fig.3) use of rapid hardening cement gives a more rapid set which, however, may not be advantageous. Sulphate resisting cement appears to be of little value in treating sulphate-rich clay soils. Rapid-hardening cement containing Calcium Chloride can be effective in stabilising organic-rich soils.

(ii) Lime: The strength developed in different soil types by admixture of lime has shown that the presence of clay is essential for appreciable strength gain. There is a voluminous literature on lime stabilisation for road construction but the marked lack of technical data is clear evidence that factors other than material performance are significant. Generally it can be said that the compressive strength of a lime-soil mixture increased with lime content at a decreasing rate.

(iii) Bitumen: Bitumen provides cohesion in granular materials and improves stabilising of most material in water. Bitumen is not popular from building blocks point of view. However for highways, bitumen is extensively used to stabilise the sub base.

(iv) Other additives: Numerous attempts have been made to stabilise soils with a very wide variety of additives. Many of them, e.g. Polymers, are excellent stabilisers, but generally they are more expensive than cement or lime.

Stabilised Blocks:

In the following paragraphs some typical results are presented with regard to the stabilised blocks. Figure 1 illustrate the effect of density on the compressive strength of the blocks (29x14x9cms) without any additives compacted at a moisture content of 18 . The dominent influence of density is evident. Commercially burnt brick has a compressive of strength of about 30 kg/cm^2. The strength of compressed block can easily exceed this value provided the required density could be achieved. The tensile strength is also shown in the figure. Values obtained are from about 0.6 kg/cm^2 (density = 1.39 gms/cc) to 7 Kg/cm^2 (density = 1.98 gms/cc). The burnt brick has a value of about 2.6 kg/cm^2.

Fig. 2 illustrates the compressive strength vs. density of cement(7.42) stabilised block. The increase in strength with cement as additive is evident. The tensile strength also got increased. Fig. 3 shows the effect of percentage of cement on the compressive and tensile strength. There is a steady increase of strength(both compressive and tensile) with percent of cement. Fig. 4 shows the influence of curing time on the strength for block with and without additives. The relative performance is clear and evident.

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TABLE 1

TYPICAL PROPERTIES OF CEMENT STABILISED SOILS

Soil Type	Strength Range lbs/sq in	'E' value (lbs/sq in)	Volume change	Remarks
Well graded gravel-Sand clay; Sands or gravels	400-1500 and more. Ratio of Wet/dry strength 1:1.5	$1\text{-}3X10^6$	Very small less than 1% (Concrete 0.1%)	Material is more suitable for bituminous stabilisation
Silty Sand, Sandy clays, Sand and gravel	250-500	$1X10^6$	Small	Good material. Suitable for bituminuous stabilisation
Silty sandy clays; Partly graded sands	100-250	$0.5\text{-}1X10^6$	-	Compaction difficulties in sand. Limit of bituminous stabilisation
Silt , silty clays, very poorly graded soils	50-150	Less than $5X10^5$	-	-
Heavy clays; organic and sulphate rich soils	<100 Ratio of wet/ dry strength 1:3	Upto $2X10^5$	High	Extreme difficulty inmixing use of lime could be beneficial.

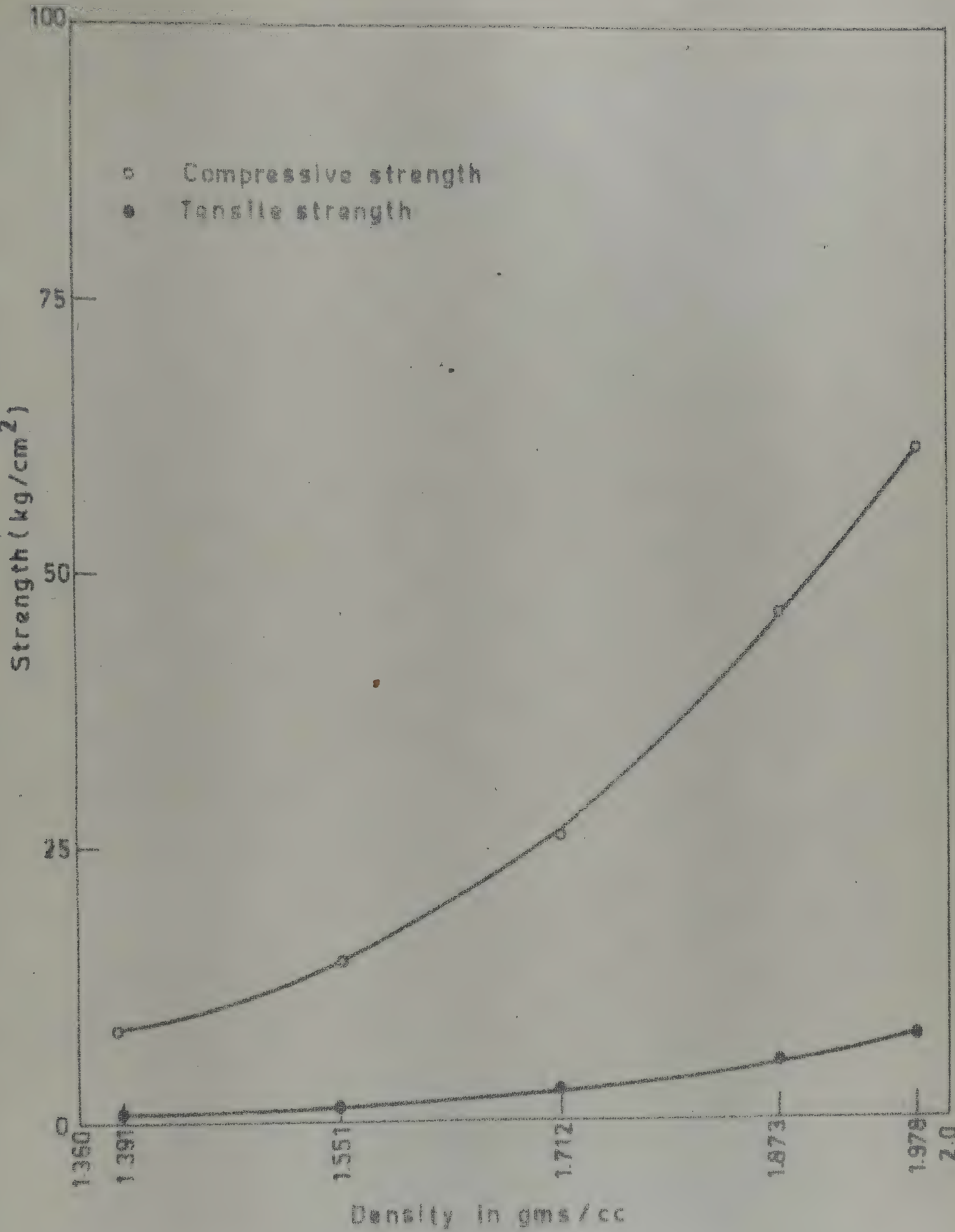

FIG.1-DENSITY Vs STRENGTH FOR RED EARTH
(Air dried for 28 days)

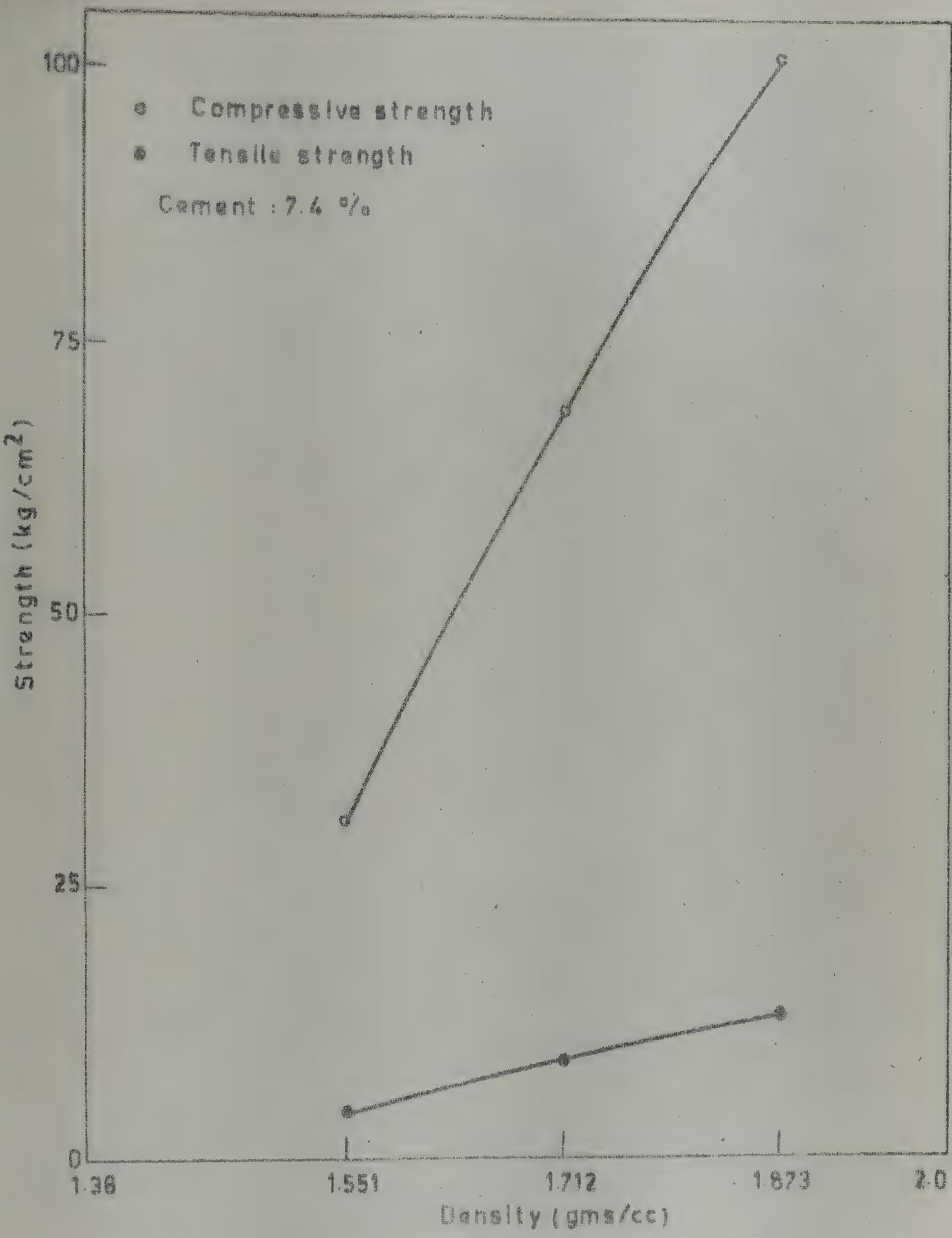

FIG.2 - DENSITY Vs STRENGTH OF CEMENT STABILISED RED EARTH

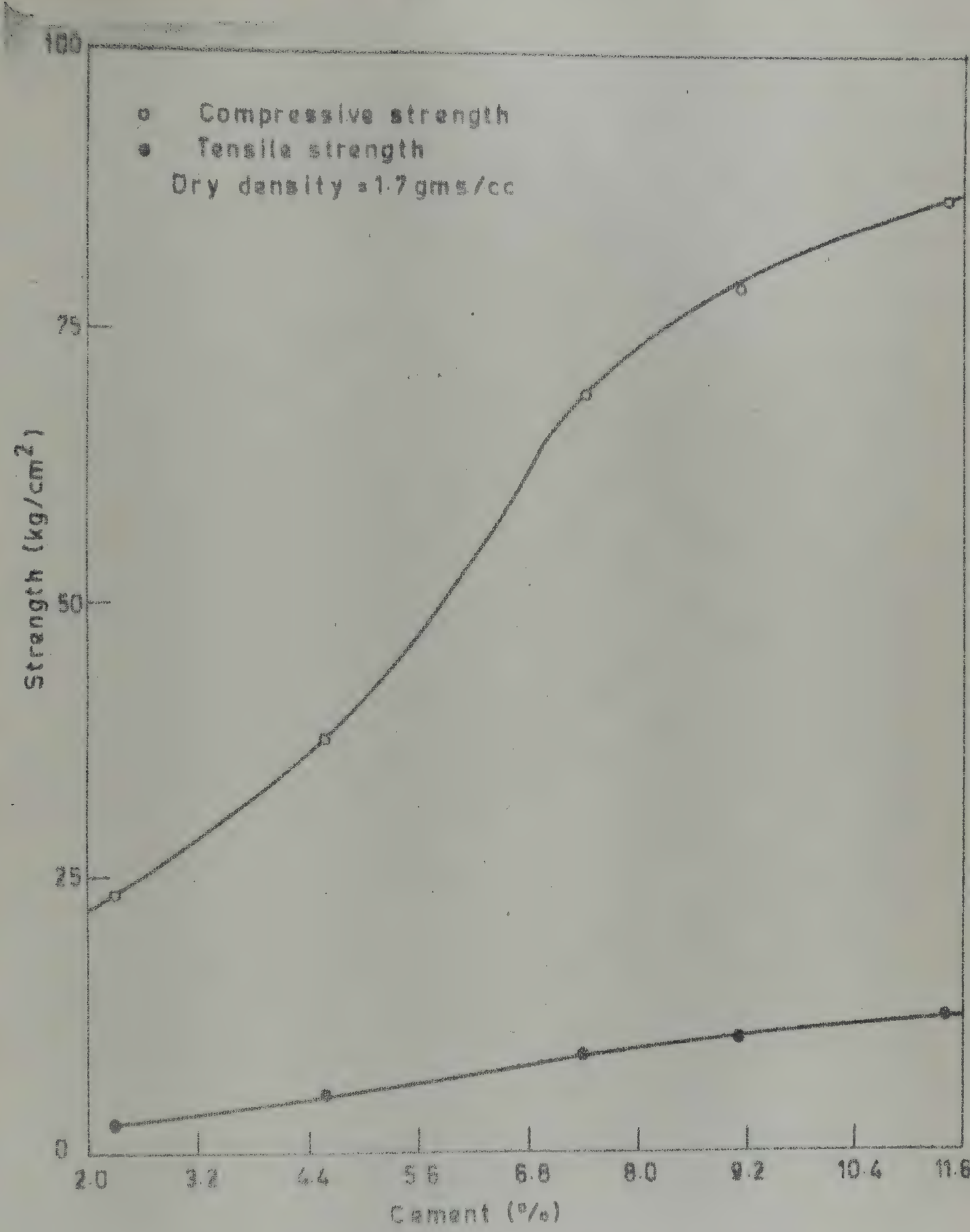

FIG. 3 - PERCENTAGE OF CEMENT Vs STRENGTH OF RED EARTH

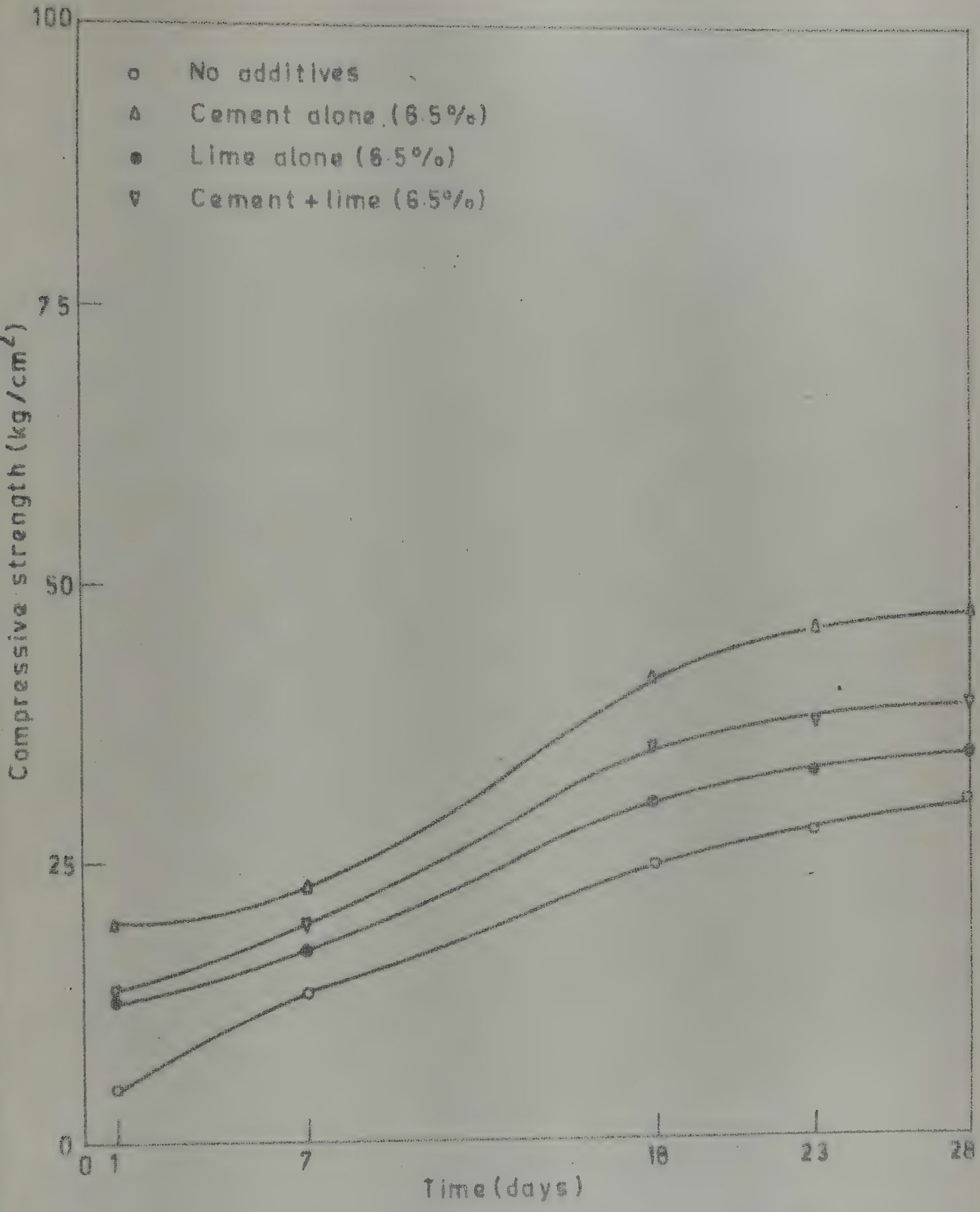

FIG 4 - EFFECT OF CURING TIME ON THE COMPRESSIVE STRENGTH

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SOME ASPECTS OF DESIGN AND PERFORMANCE OF FOUNDATIONS AND WALLS IN RURAL HOUSES

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Lecture 6.7
Rural Technology Course

Mud wall construction dates back to the beginning of civilization. Being abundant and inexpensive it formed an automatic choice. Even to this day, the majority of houses in the developing countries are of mud walls. Moriarty (1978) reports that in Tanzania, 95% of the houses are built of earth. As per 1971 census, out of 123 million houses in our country, 61 million houses were made of mud walls or sun-dried mud brick walls. There is thus an urgent need of collecting the information on various traditional construction methods and of subjecting them to scientific investigations in order to improve and standardise the technique. If the real drawbacks are scientifically studied and attempts made to improve the performance characteristics, mud wall construction can become technically a very attractive proposition not only for the village poor but also for others living in towns and cities. Subba Rao(1979) has discussed certain aspects of design and performance of foundations and walls in rural houses. Further discussion will be presented in this paper. Attention will be focussed on the design of foundations and the necessity of it, and on walls made of sundried bricks and of rammed earth. Other forms of wall construction like mud and stone walls, reinforced mud walls etc. are outside the scope of present article.

Loads, Bearing Capacity and Foundations

The intensity of load at the base of walls of rural

houses which are mostly single storeyed but only occassionally two-storeyed is usually of the order of 1/2kg/cm^2 and rarely exceeds 1.0 kg/cm^2. This is usually because of dwarf walls and light roofs. Most of the soils have adequate strength to support the above load intensity. Table 1 reports the safe bearing capacity(with factor of safety of 2.5) of soils for a wall foundation of width 0.45m and depth 0.5m.

Table 1. Safe Bearing Capacity(SBC) of Continuous Foundation(width 0.45m, depth 0.5m).

Cohesive Soils			Cohesionless soils			
Consistency	Undrained shear strength kg/cm^2	SBC kg/cm^2	Compactness	Relative density	SBC kg/cm^2 Silty sands	Sand
Very Soft	less than 0.25	Less than 0.6	Very loose	less than 0.2	less than 0.8	less than 1.4
Soft	0.25 to 0.50	0.6 to 1.2	loose	0.2 to 0.4	0.8 to 1.4	1.4 to 2.7
Medium	0.5 to 1.0	1.2 to 2.4	Medium	0.4 to 0.6	1.4 to 2.7	2.7 to 5.6
Stiff	1.0 to 2.0	2.4 to 4	Dense	0.6 to 0.8	2.7 to 5 6	5.6 to 13.3
Very stiff	2.0 to 4.0	4.6 to 9.2	Very dense	0.8 to 1.0	greater than 5.6	greater than 13.3
Hard	Greater than 4.0	Greater than 9.2				

Walls of rural houses vary in thickness considerably. Usually they are 25 cm thick but thicknesses as high as 75 cm(Prakash and Singh, 1978) have been reported. Mud walls are made thick for two reasons: a) thicker the wall, better is its strength against erosion and b) thicker the wall, better is the thermal comfort. Thickness of sundried brick walls is usually 25 cms, and the plaster thickness another 5 cm. So, barring a few exceptions, most of the foundations will have to be in the range of 30 to 50 cm thick.

Often, rural houses will have no adequate foundations and sometimes no foundations at all as a survey in Tanzania indicated (Moriarty, 1978). It may often be felt that loading being so small, the building warrants no foundation. Table 1 also lends support to the argument. Even for surface foundations, the figures in the table remain practically unaltered. One important factor which however is likely to be ignored is that the durability and performance of walls are closely linked with that of the foundation, particularly if the walls are made of mud. Two important functions a foundation performs apart from merely transmitting the load to the soil are: i) it protects and isolates the wall from the influence of moisture fluctuations in the ground and ii) by providing a solid support to the loading, it minimizes the differential movements in the body of the wall. Poor performance of walls often would be due to inadequate foundations than due to intrinsic inadequacy of wall material

itself. Adequate foundation, therefore, is a must for rural houses if they have to perform satisfactorily.

Adequacy of foundation is decided by the considerations of bearing capacity, settlement and the depth of embedment. The first two criteria are related to stress and strain, ie., possible overloading or undue deformation of soil. We have already seen that they pose no problem since even a surface footing satisfies the criteria. The third criterion relates to the effects of external influences which are a function of the site and of the type of soil but which are independent of the building and the load. Determination of the embedment required to offset the influences of erosion or volume changes in the soil due to changes in moisture content or chemical reaction is based more on judgement than on analysis.

Indian Standard Code of Practice for design and construction of simple spread foundations, IS 1080-1962, contains the following specifications:

'Detailed design is not required for spread foundations for light structures as normal requirements will generally be sufficient to bring the bearing pressure within the safe limits'.

'Clay soils are seasonally affected by drying shrinkage and cracking in hot summers and by swelling in the following wet weather, to a depth which will vary according to the nature of the clay. The possibility of these movements shall

be considered particularly in the case of small dwellings'.

'It is necessary in these soils to place the foundation bearing at such a depth where the effects of seasonal changes are not important'.

Again, IS 1904-1966, the code on the structural safety of foundations stipulates, the foundation in any type of soil shall go below the zone significantly weakened by roof holes or cavities produced by burrowing animals or worms. The depth shall also be enough to prevent the rain water scouring below the footings'.

Our national codes had earlier stipulated a minimum depth of 50 cms below natural ground. Later the figure has been revised to 30 cms. Thus notwithstanding the type of wall and the loading, depth of foundations even for rural houses should be about 30 to 50 cm below natural ground. The foundation block may be constructed either with stone or concrete or even stabilized blocks but needs to be definitely as rigid and impermeable as possible.

Table 1 gave safe bearing capacity values for cohesive and non-cohesive soils. For a general cohesion-friction soil (C - ϕ soil), the safe bearing capacity of a continuous foundation is given by

$$SBC = \frac{1}{F}\left[CN_c + \gamma D_f(N_q - 1) + \tfrac{1}{2}\gamma B N_\gamma\right] + \gamma D_f \quad \cdots\cdots \quad (1)$$

in which

SBC = safe bearing capacity, kg/cm^2

F = factor of safety against bearing failure,

C = Cohesion, kg/cm^2

N_c, N_q, N_γ = bearing capacity factors dependent on angle of internal friction ϕ degrees,

γ = effective unit weight of soil, kg/cm^3

D_f = embedment of foundation, cm,

B = width of foundation, cm.

Bearing a few problem soils like highly organic peats, highly expansive clays, very soft and sensitive marine deposits etc., for most of the soils in warm climates the safe values of C and ϕ can be assumed as C = 0.5 kg/cm^2 and $\phi = 20^o$. The corresponding bearing capacity factors become $N_c = 17.7$, $N_q = 7.4$ and $N_\gamma = 5.0$. For D_f = 30 to 50 cms and B = 30 to 50 cms, the safe bearing capacity is about 3.7 kg/cm^2. For the values assumed, the effect of B, D_f and the position of the water table are only marginal (less than 1%). The elastic settlement of foundation is given by

$$S_i = \frac{(1 - \mu^2)\ q.\ B}{E} \qquad \ldots (2)$$

in which μ = poisson's ratio

q = loading intensity

B = width of foundation

E = elastic modulus

For clays, usual range of E is from 500 to 2000 times the undrained shear strength. It can readily be seen that the

immediate settlement for the associated range of values is quite negligible, less than 0.2 cm.

The total settlement of foundation is given by

$$S = m_v . (\triangle p) . H \qquad .. (3)$$

in which m_v = volume compressibility, cm^2/kg

$\triangle p$ = pressure increment due to applied load, kg/cm^2

H = thickness of compressible layer, cm.

Even for a high value of m_v of the order of 0.03 cm^2/kg, the total settlement of foundations of rural houses will be in the range of 0.5 cm to 1.5 cm for the load range of 0.5 kg/cm^2 to 1.0 kg/cm^2.

Strength and Durability of Walls and Wall Elements

Indian Standards IS 1905-1969 lists the various factors influencing the structural adequacy of walls. The required crushing strength of brick(wall element) for a single storey rural house with loading of $\frac{1}{2}$ kg/cm^2 comes to about 6 kg/cm^2. This is the wet strength or when the wall element is totally wet. Soil blocks show considerable reduction in strength upon wetting. The reduction can be as high as 75%.

It is because of such reduction in strength upon wetting, the soil blocks are not very durable. The design and performance of walls are therefore based on twin criteria:

1) Dry and wet strengths and 2) Erosion characteristics.

A comparison of crushing strengths of burnt brick walls and sundried brick walls built in mud mortar is available from Yogananda et al.(1979). Table 2 reports the strengths.

Table 2. Strength of walls in mud mortar.

Table 2. Strengths of Walls in mud mortar(Yogananda et al. 1979)

Sl. No.	Wall height, m	Crushing strength, kg/cm^2					
		Sundried bricks			Burnt bricks		
		Wall thickness 10 cms	20 cms	30 cms	10 cms	20 cms	30 cms
1	1.0	4.6	4.05	3.9	7.2	7.25	6.6
2	1.2	4.1	3.6	3.07	6.1	6.7	6.03
3	1.5	3.6	3.0	2.53	5.4	5.85	4.4
4	2.0	2.8	2.15	2.03	4.1	4.4	3.57

Average crushing strengths of individual sundried bricks and burnt bricks were respectively 10.0 kg/cm^2 and 11.15 kg/cm^2.

It can be observed that the reduction in strength with slenderness ratio for sundried bricks is of the same order as for burnt bricks. The strength of masonry with mud mortar for a 1.5m to 2.0m high wall is of the order of 25% to 35% in the case of sundried bricks and 40% to 50% in the case of burnt bricks. The writer has conducted tests on masonry blocks involving 2 and 3 layers of brickwork in mud mortar.

The results indicate that the masonry in mud mortar has a strength of about 50 to 60% of the brick strength.

Shivananda et al (1979) provide comparison between Cob method of construction and rammed earth construction corresponding to Proctor optimum. Table 3 contains the results.

Table 3. Strength of rammed earth walls(Shivananda et al 1979)

Sl. No.	Wall thickness cm	Crushing strength, kg/cm^2	
		Rammed earth wall	Conventionally build (Cob method)
1	20	0.3	0.2
2	30	0.43	0.27
3	45	0.58	0.33

Wall height = 90 cm, Wall length = 1m.

Reinhold Pingel (1975) also reports a marked improvement of rammed earth over conventionally placed earth. Table 4 contains cube strengths.

Table 4. Crushing strengths of mud cubes (Reinhold Pingel, 1975)

	Crushing strength of 15 cm cubes kg/cm²			
	1	2	3	Average
Traditional mud mix, 40-50 sand	2.1	1.6	2.4	1.7
Traditional mud mix rammed into mold	6.4	6.8	6.0	6.4
Mud mix 20% sand and 25% pebbles rammed	4.9	3.0	3.4	3.7

All the above test results, however, are only dry strengths. Comparisons of strengths when the wall elements and walls are partially or fully wet are not yet available. A minimum wet strength of about 1.4 MN/m^2 has been recommended by several building authorities throughout the world (Lunt).

Erosion of mud walls is caused mostly by the impact of rain water directly on the walls or by the impact of rebound particles of water Wind-borne rain has its greatest erosive effect at the bottom of the wall, as does erosion from rain splash up. Prolonged rain fall during the hottest months will cause a raise in the water table, and in low lying or poorly drained areas, moisture will be taken up into the walls by capillary action. The increase in water content

will lead to strength reduction, especially at the wall base, where compression stresses are greatest, as well as increasing the dead weight of the wall, and thus the overall stresses.

Thus the compressive load is increased by the increasing water content resulting from capillary moisture rise, the compression strength is simultaneously reduced by this rising capillary moisture, especially at wall base level, while erosion tends to reduce the cross section at wall base' (Moriarty, 1978).

Erosion characteristics of mud walls and the actual weathering performance of walls are still not well understood. Wall elements are usually subjected to alternate wetting and drying as per IS 1725-1960 or other modifications. Tests on weight loss when wall elements are put against water jets (simulating rain) are also conducted. By and large, stornger the wall, greater is its resistance against erosion. Tests with water jets have indicated that walls made of well graded coarse soils with just sufficient fine fraction to bind them have a greater erosion resistance(Vaidyanathan and Ramaswamy, 1978). The writer's tests of alternate wetting and drying on Budiguppe soil also confirm the above finding. Budiguppe soil is traditionally known to possess excellent qualities for mud wall construction. Test showed that it is well graded silty sand with only 25% passing No.200 sieve(75μ size).

It is non-plastic having liquid limit of 28% . Allam and Sridharan(1981) have shown that alternate wetting and drying creates desiccation bonds in the soil and thus improves the characteristics with time. Budiguppe soil showed a strength increase of the order of 100% after about 8 cycles of wetting and drying alone essentially in the same way as Allam and Sridharan.

Such tests as above provide useful information on the erosion characteristics of wall elements and can be used to study the relative merits of different wall types. However the weathering is a more complicated phenomenon than depicted by simple tests. Correlations between the actual weathering performance and those with different tests(alternate wetting and drying, rain simulation etc.) are still unknown.

Concluding Remarks

In the above paragraphs, attention has been drawn to certain basic problems of strength and durability of mud walls which require further research. The present knowledge though clearly insufficient in parts, is however enough to indicate that before long earth wall construction can be made totally acceptable from all requirements of strength, stability and durability.

The following general points help to improve the performance of mud walls:

1. An adequate foundation is a must for any house if it has to last long.

2. Mud walls should be sufficiently thick, say 25 cms, to provide thermal comfort and resistance against moisture.

3. Walls should be shielded as much as possible from the erosive effects of rain by providing generous roof overhangs and by protecting the base of the wall to a height of at least 25 cms by proper skirting.

4. Prevent erosion of wall surface from running water by providing projection to window cills.

5. Provide proper drainage in the site and do not let vegetation to grout around the walls.

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